US007521719B2

(12) United States Patent
Schranz

(10) **Patent No.: US 7,521,719 B2**
(45) **Date of Patent: Apr. 21, 2009**

(54) **LIGHT EMITTING AND IMAGE SENSING DEVICE AND APPARATUS**

(76) Inventor: **Paul Steven Schranz**, Box G-30 RR1, 1270 Oceanview Road, Bowen Island, British Columbia (CA) V0N 1G0

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/775,224**

(22) Filed: **Jul. 9, 2007**

(65) **Prior Publication Data**

US 2008/0012029 A1 Jan. 17, 2008

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/917,377, filed on Aug. 13, 2004, now Pat. No. 7,242,027.

(51) **Int. Cl.**
H01L 33/00 (2006.01)

(52) **U.S. Cl.** **257/80**; 257/225; 257/E33.076

(58) **Field of Classification Search** 257/80, 257/225, E33.076
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,371,384	A *	12/1994	Wada	257/82
5,493,577	A *	2/1996	Choquette et al.	372/46.013
5,629,534	A *	5/1997	Inuzuka et al.	257/84
5,965,875	A *	10/1999	Merrill	250/226
6,122,042	A *	9/2000	Wunderman et al.	356/73
6,151,015	A	11/2000	Badyal et al.	
6,281,882	B1	8/2001	Gordon et al.	
6,339,248	B1 *	1/2002	Zhao et al.	257/461
6,433,780	B1	8/2002	Gordon et al.	
6,541,762	B2	4/2003	Kang et al.	
6,585,158	B2	7/2003	Norskog	
6,590,917	B2 *	7/2003	Nakayama et al.	372/45.01
6,621,483	B2	9/2003	Wallace et al.	
6,649,899	B2	11/2003	Misek	
6,657,184	B2	12/2003	Anderson et al.	
6,710,376	B2 *	3/2004	Worley	257/92
6,717,560	B2 *	4/2004	Cok et al.	345/82
6,770,863	B2	8/2004	Walley	
6,774,351	B2	8/2004	Black	
6,795,056	B2	9/2004	Norskog et al.	
6,795,120	B2	9/2004	Takagi et al.	
6,797,937	B2	9/2004	Norskog et al.	
6,809,723	B2	10/2004	Davis	
6,950,094	B2	9/2005	Gordon et al.	
6,967,321	B2	11/2005	Leong et al.	
6,974,947	B2	12/2005	Black et al.	
6,977,645	B2	12/2005	Brosnan	
6,995,748	B2	2/2006	Gordon et al.	
7,045,775	B2	5/2006	Leong et al.	
7,095,621	B2	8/2006	Saimun et al.	
7,116,427	B2	10/2006	Baney et al.	
7,146,106	B2	12/2006	Yang et al.	
7,148,078	B2	12/2006	Moyer et al.	
7,158,659	B2	1/2007	Baharav et al.	
7,161,682	B2	1/2007	Xie et al.	
7,164,782	B2	1/2007	Baharav et al.	
7,176,442	B2	2/2007	Feldmeier et al.	

(Continued)

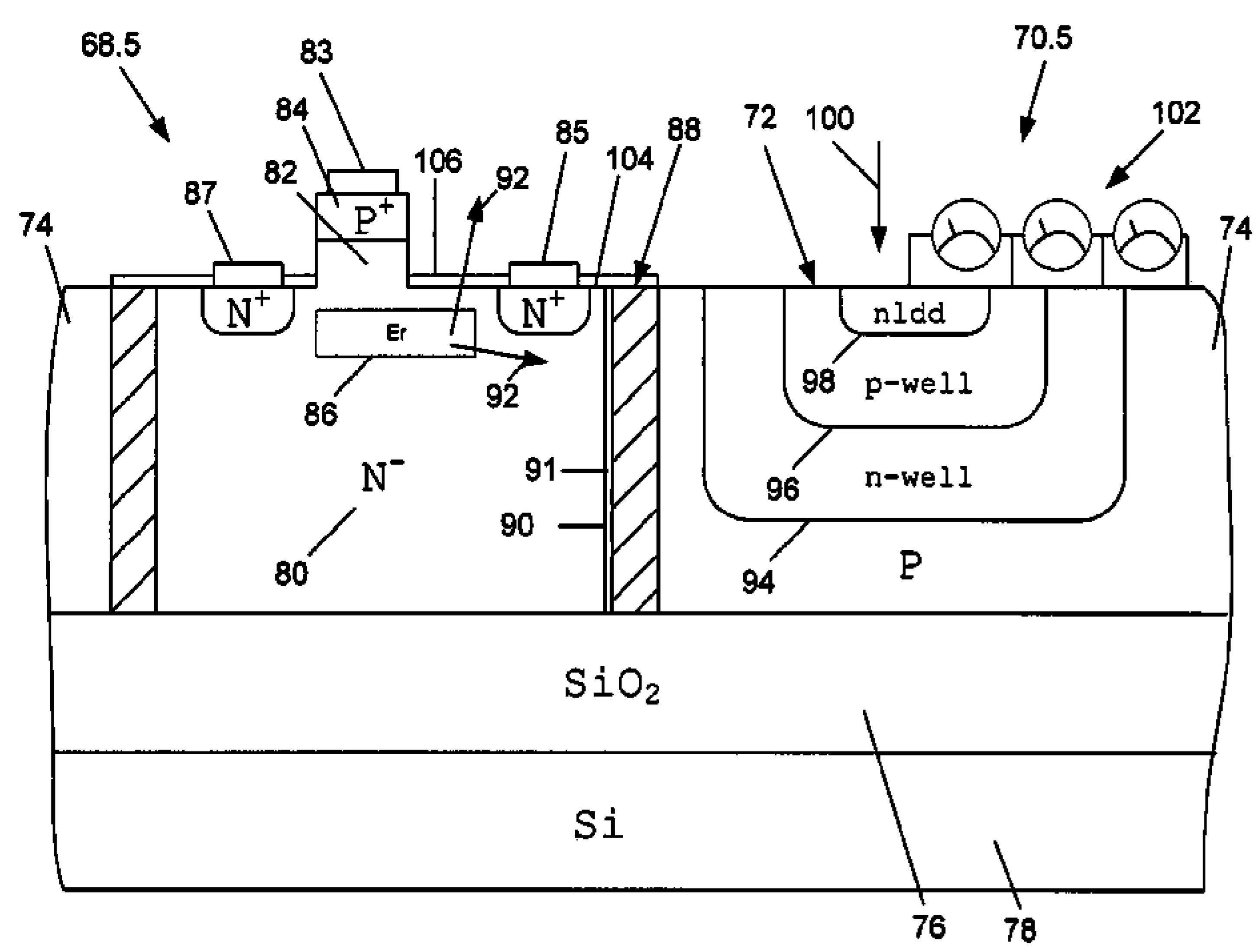
Primary Examiner—Victor A Mandala

(57) **ABSTRACT**

a photosensor structure; and

switching means coupled between the photosensor structure and one of the plurality of signal lines, the switching means responsive to select signals on one or more of the plurality of select lines for conveying a photosensor signal between the photosensor structure and the one of the plurality of signal lines.

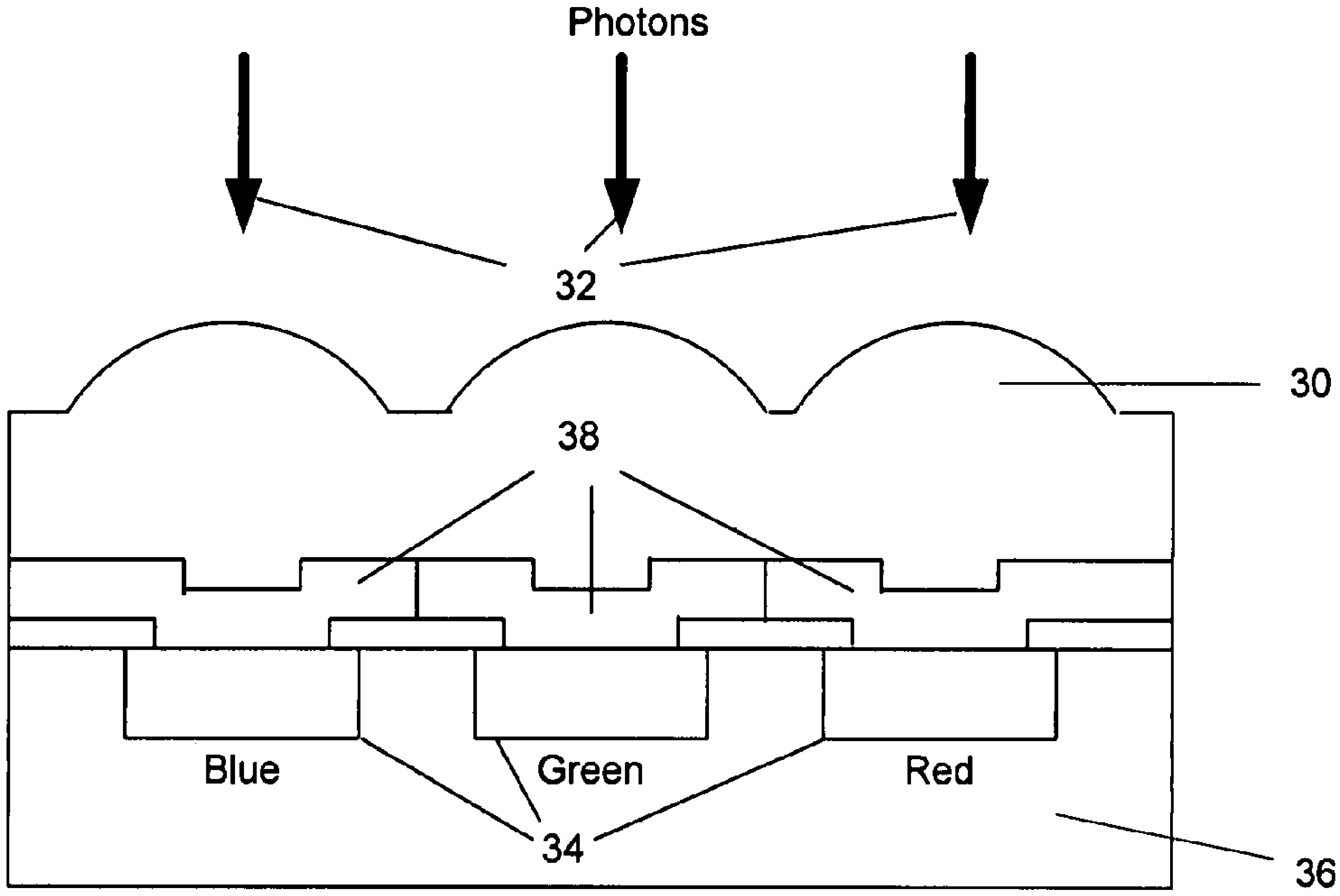
20 Claims, 22 Drawing Sheets



U.S. PATENT DOCUMENTS

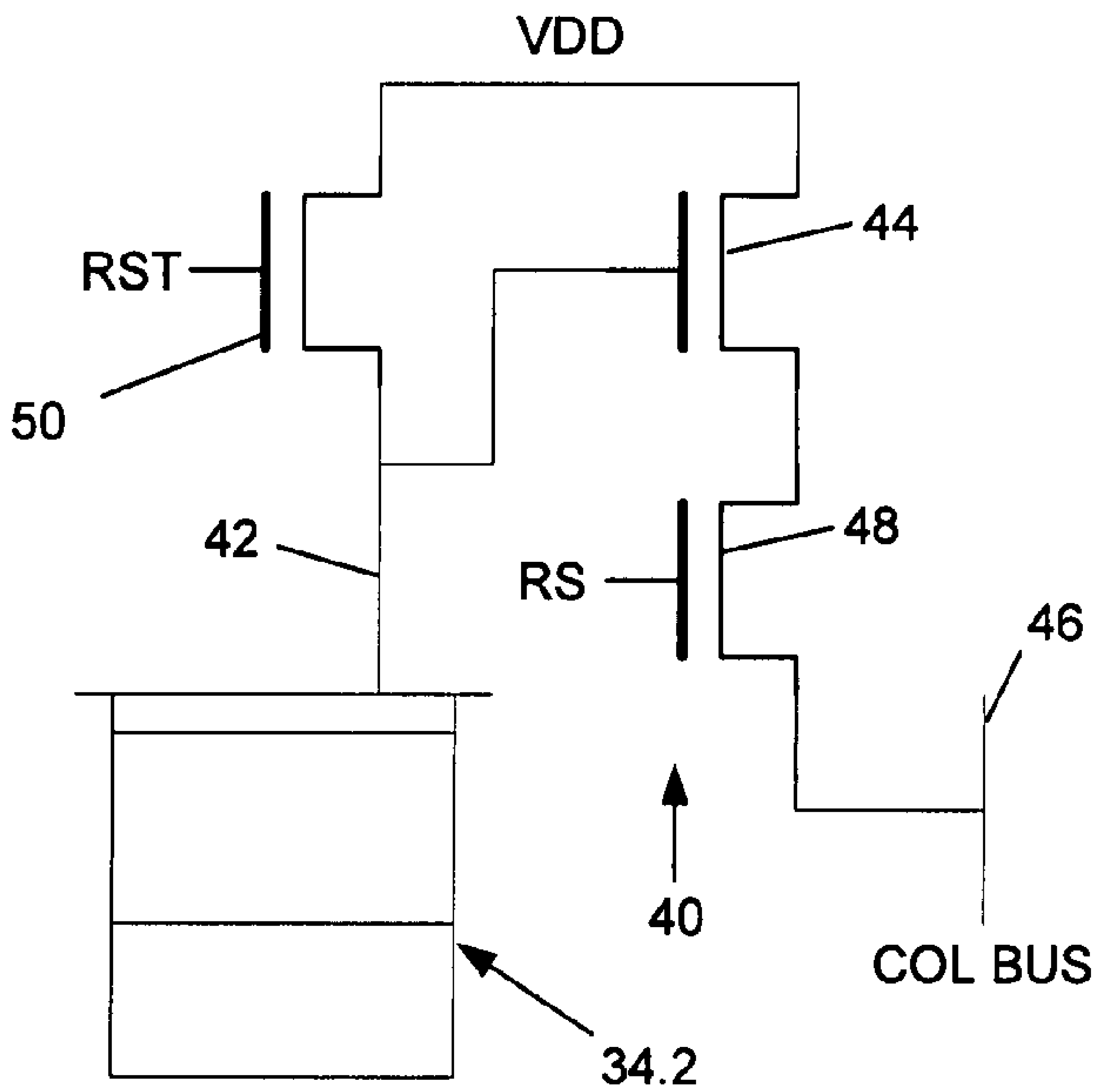
7,184,026	B2	2/2007	Gordon et al.	
7,199,783	B2	4/2007	Wenstrand et al.	
7,199,791	B2	4/2007	Sun	
7,220,956	B2	5/2007	Feldmeier et al.	
7,238,932	B2	7/2007	Chee	
7,263,242	B2	8/2007	Kakarala et al.	
7,274,808	B2	9/2007	Baharav et al.	
7,292,225	B2	11/2007	Gordon et al.	
7,295,186	B2	11/2007	Brosnan	
7,310,086	B2	12/2007	Tai et al.	
7,313,255	B2	12/2007	Machida et al.	
7,317,447	B2	1/2008	Tan et al.	
7,321,359	B2	1/2008	Xie et al.	
7,335,922	B2 *	2/2008	Plaine et al.	257/80
7,339,575	B2	3/2008	Tai et al.	
7,358,958	B2	4/2008	Welch et al.	
7,382,935	B2	6/2008	Liew et al.	
7,420,542	B2	9/2008	Butterworth et al.	
7,425,862	B2	9/2008	Thelen et al.	
7,429,976	B2	9/2008	Harley et al.	
7,446,756	B2	11/2008	Brosnan et al.	
2003/0142075	A1	7/2003	Chin	
2007/0108484	A1 *	5/2007	Nagamune et al.	257/290

* cited by examiner



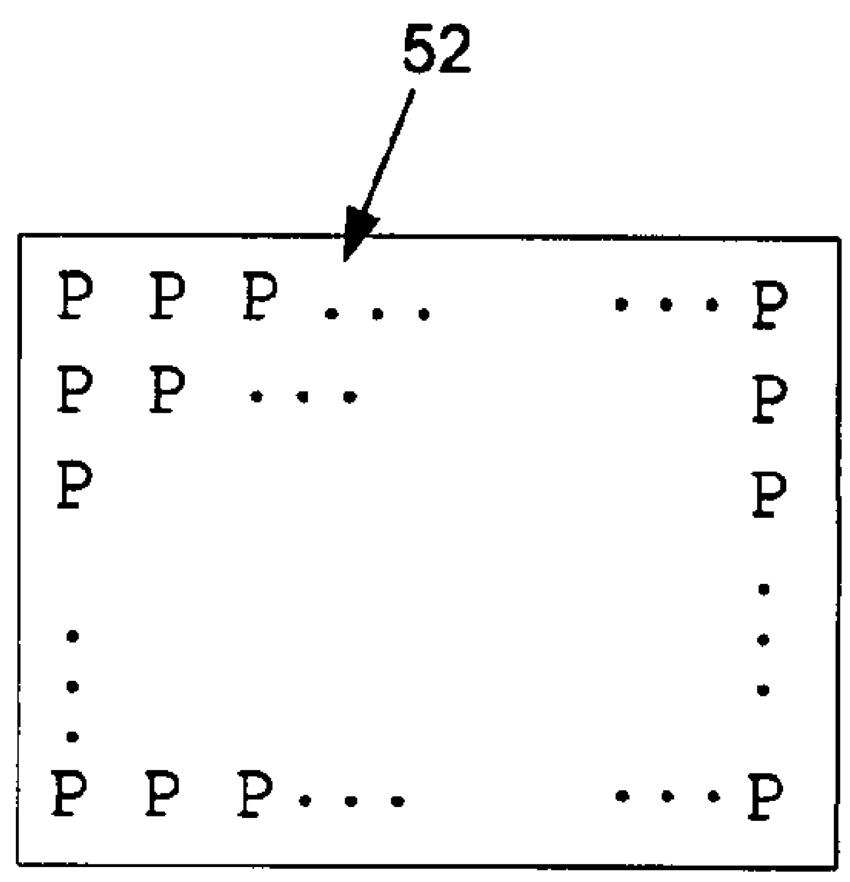
Prior Art

Figure 1



Prior Art

Figure 2



Prior Art

Figure 3

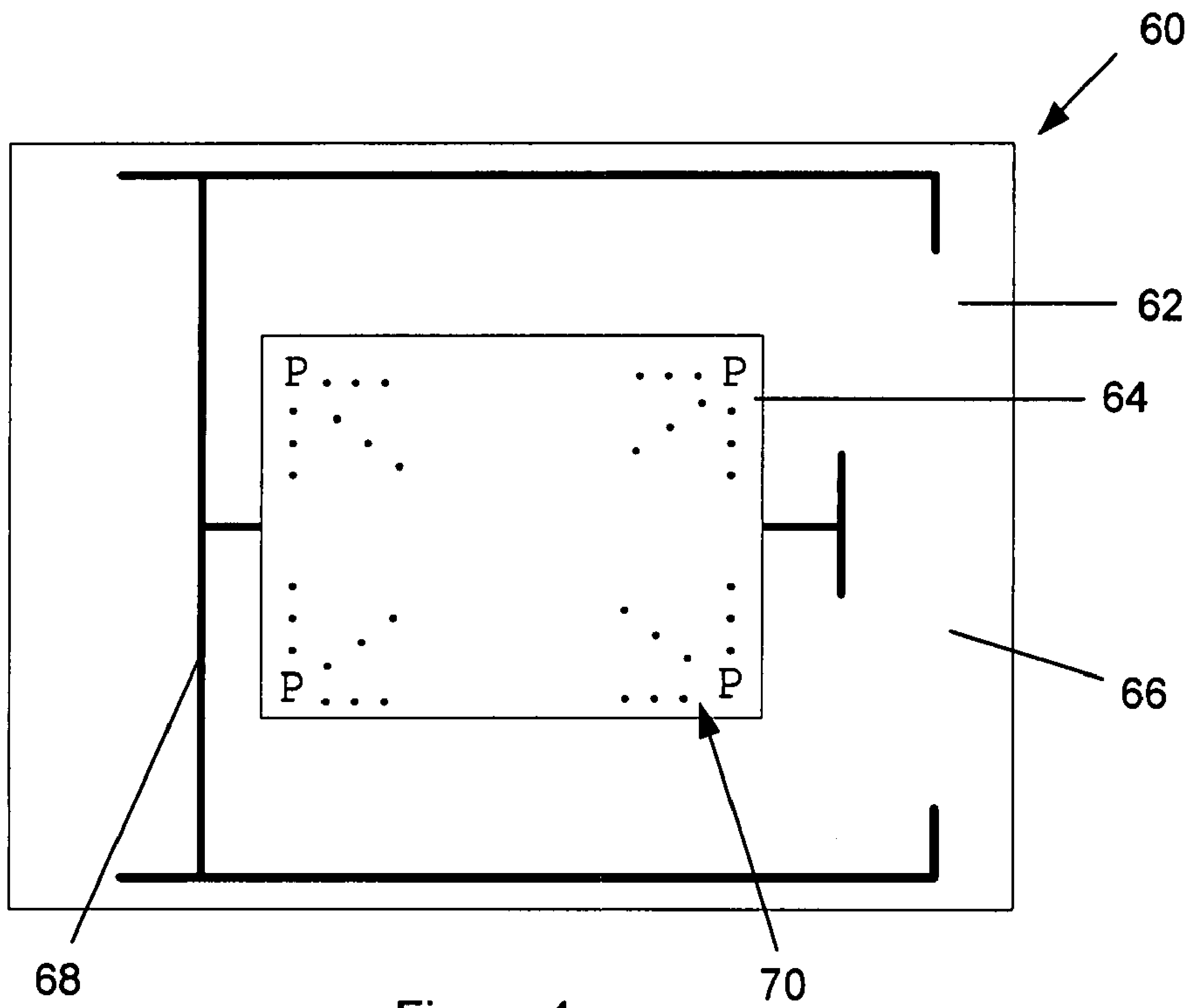


Figure 4a

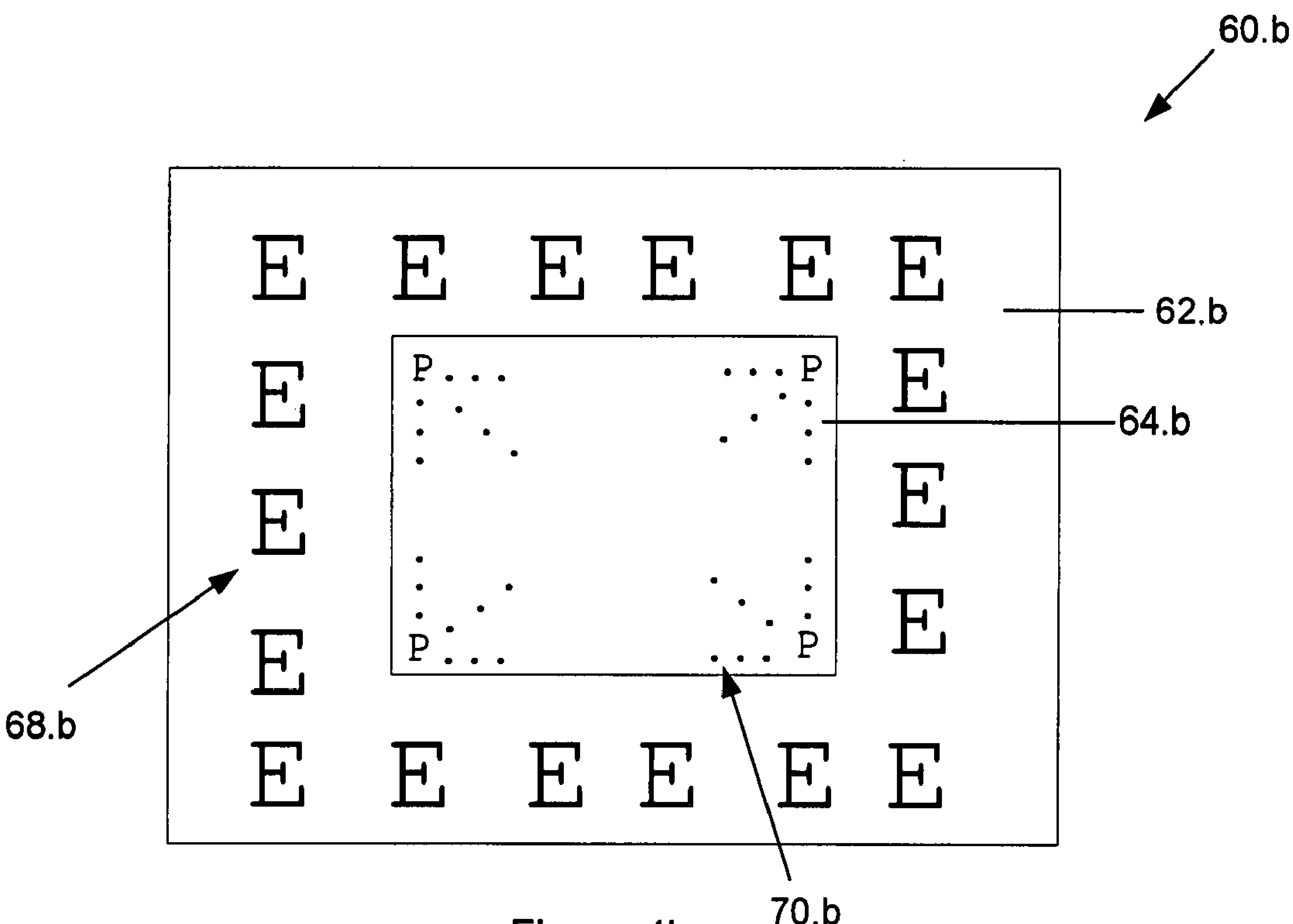


Figure 4b

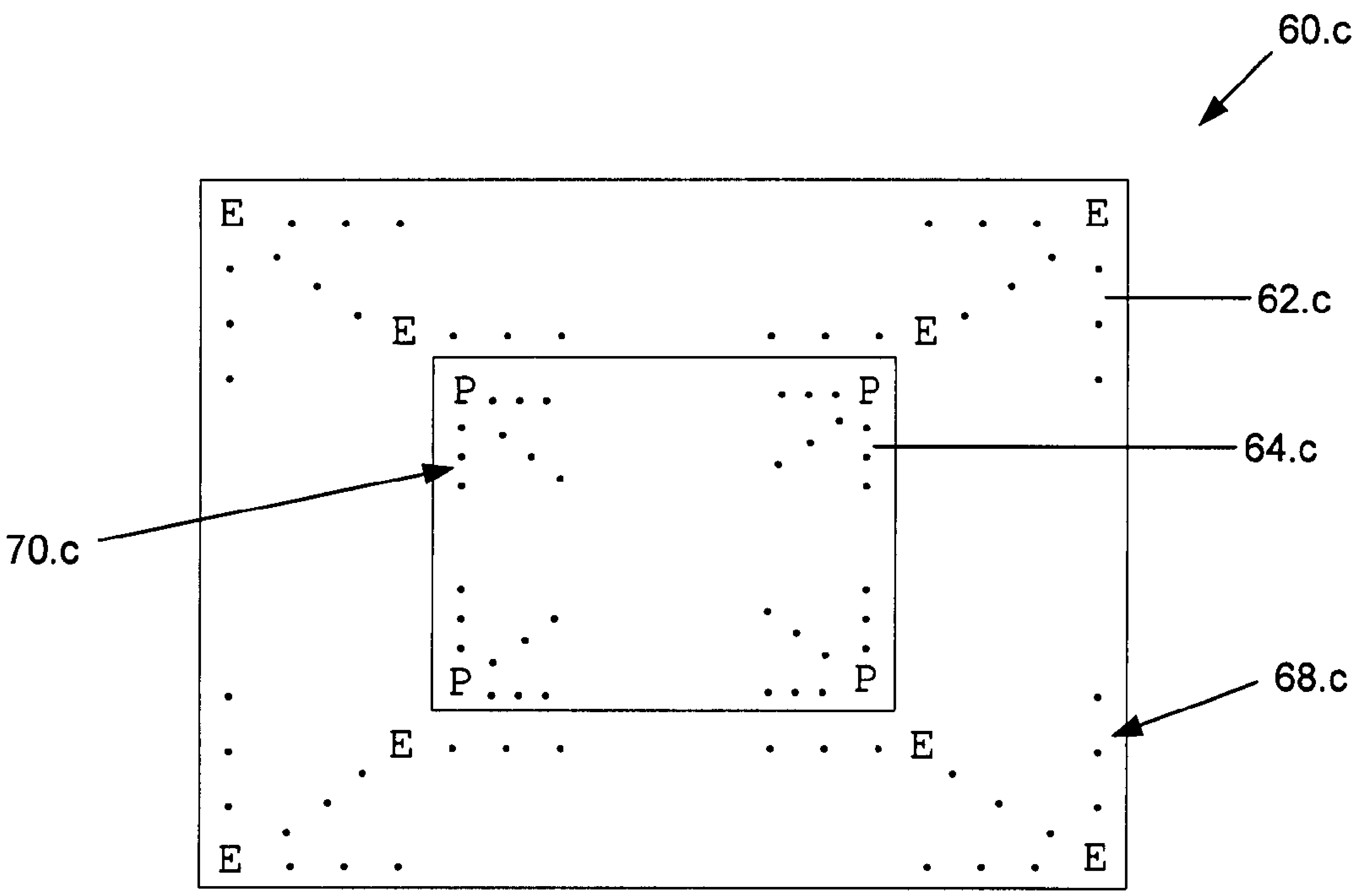


Figure 4c

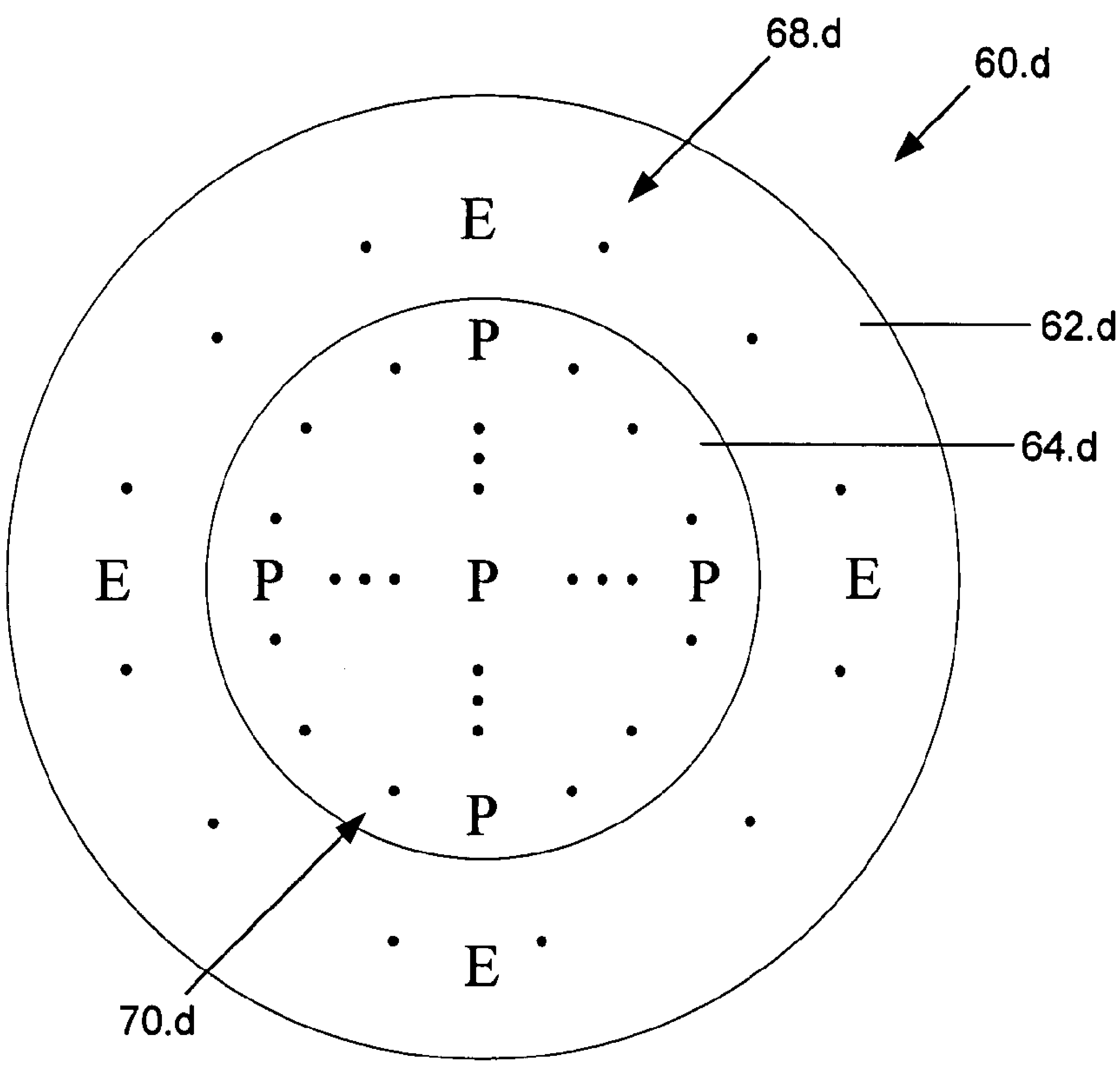


Figure 4d

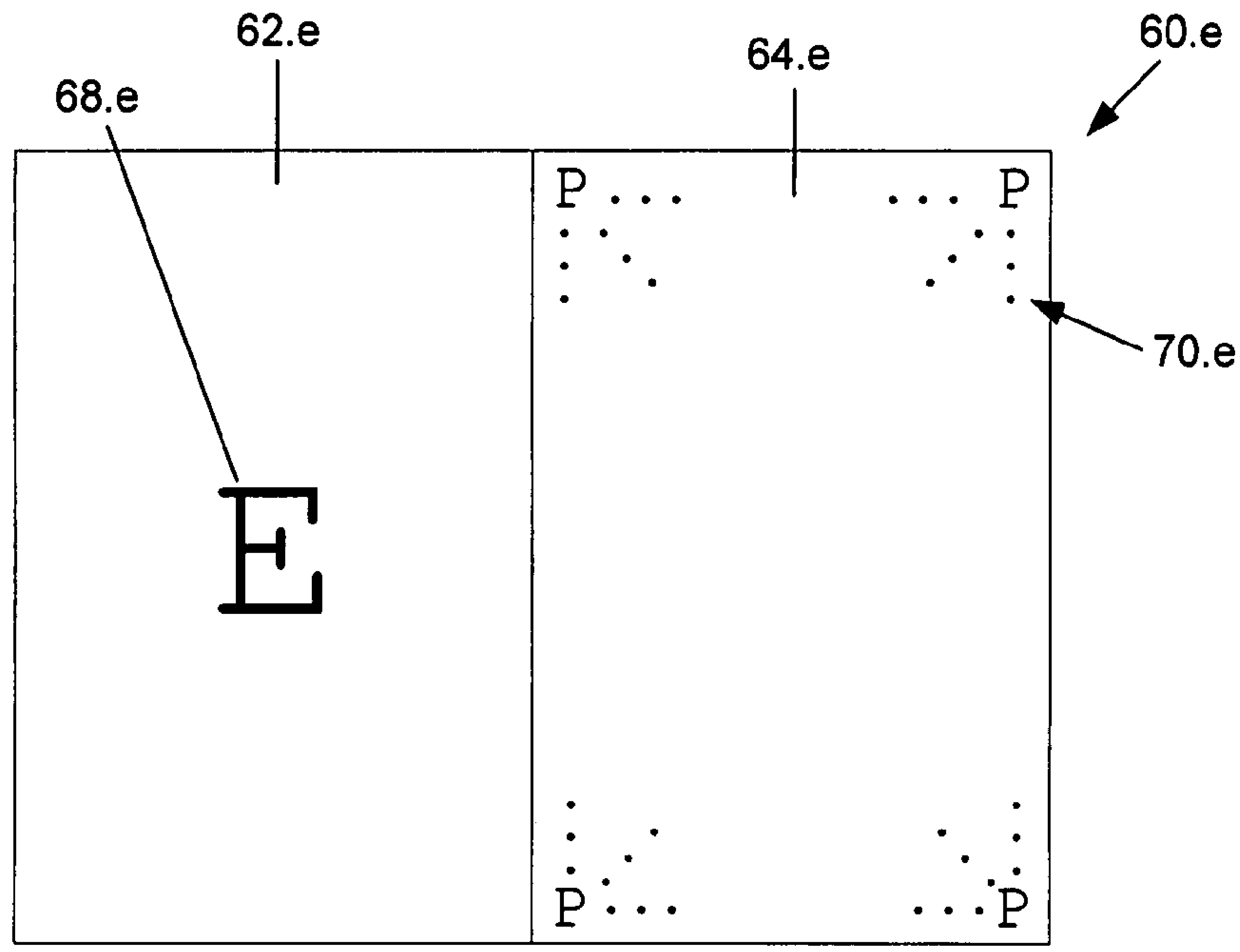


Figure 4e

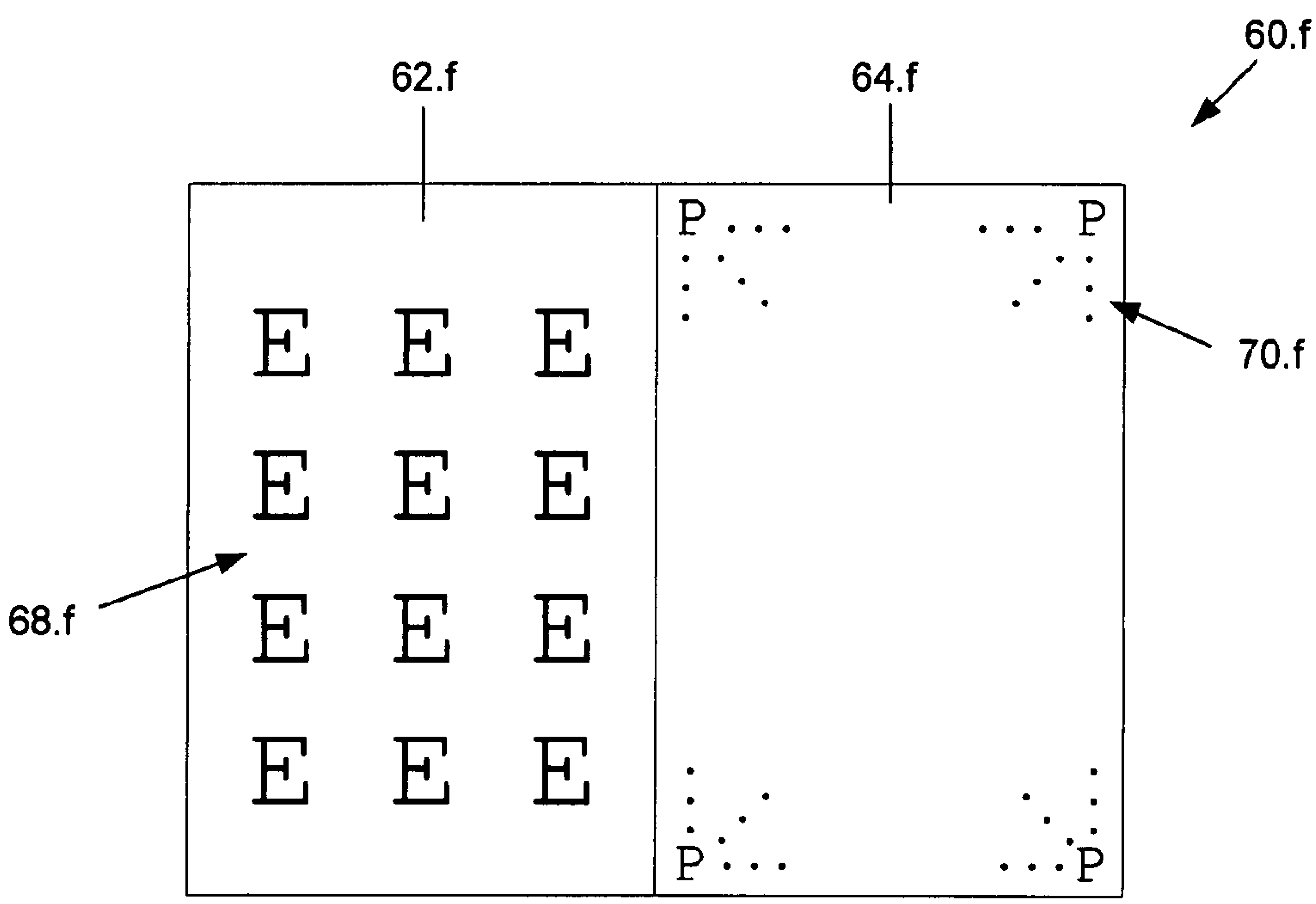


Figure 4f

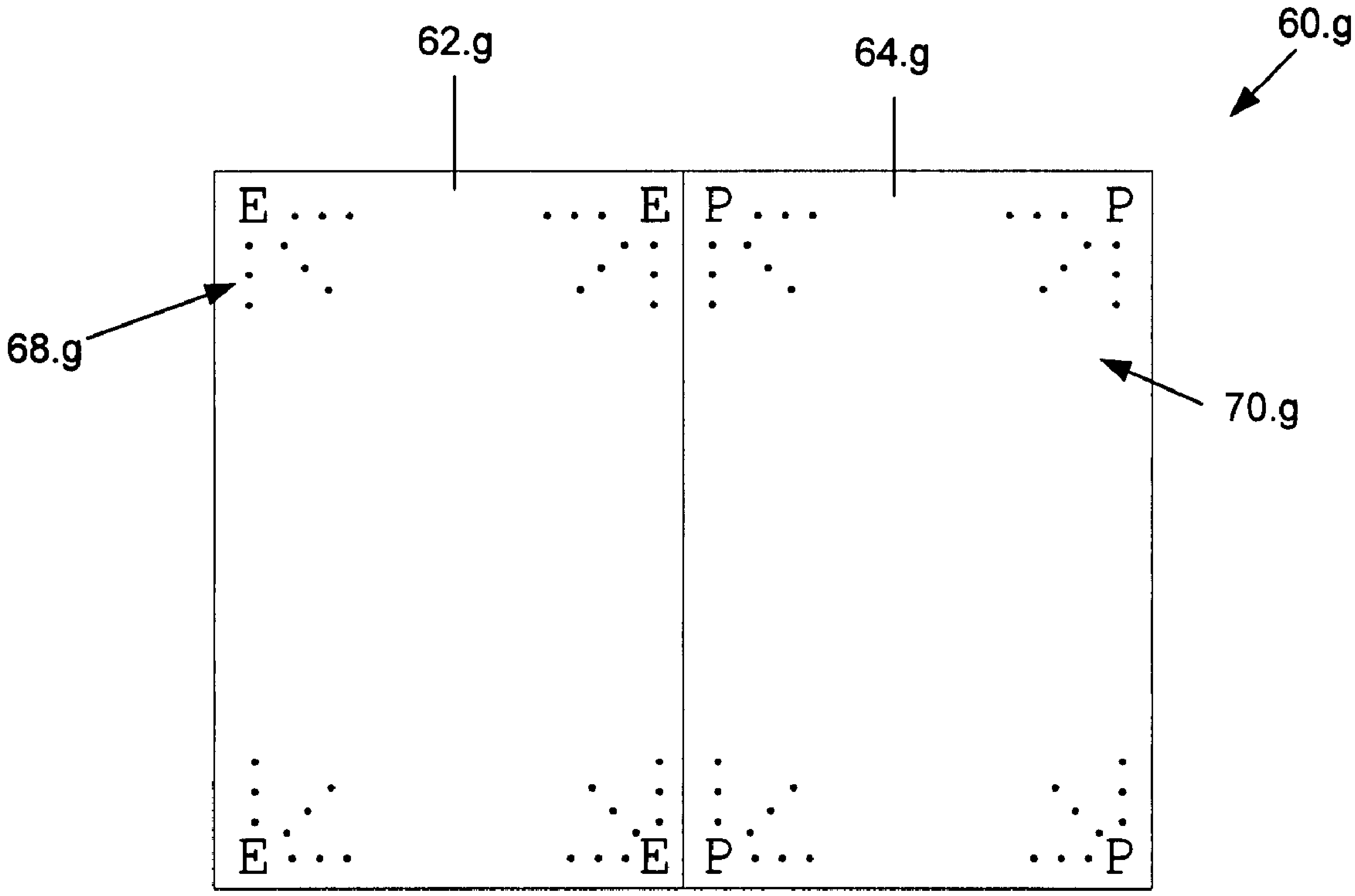


Figure 4g

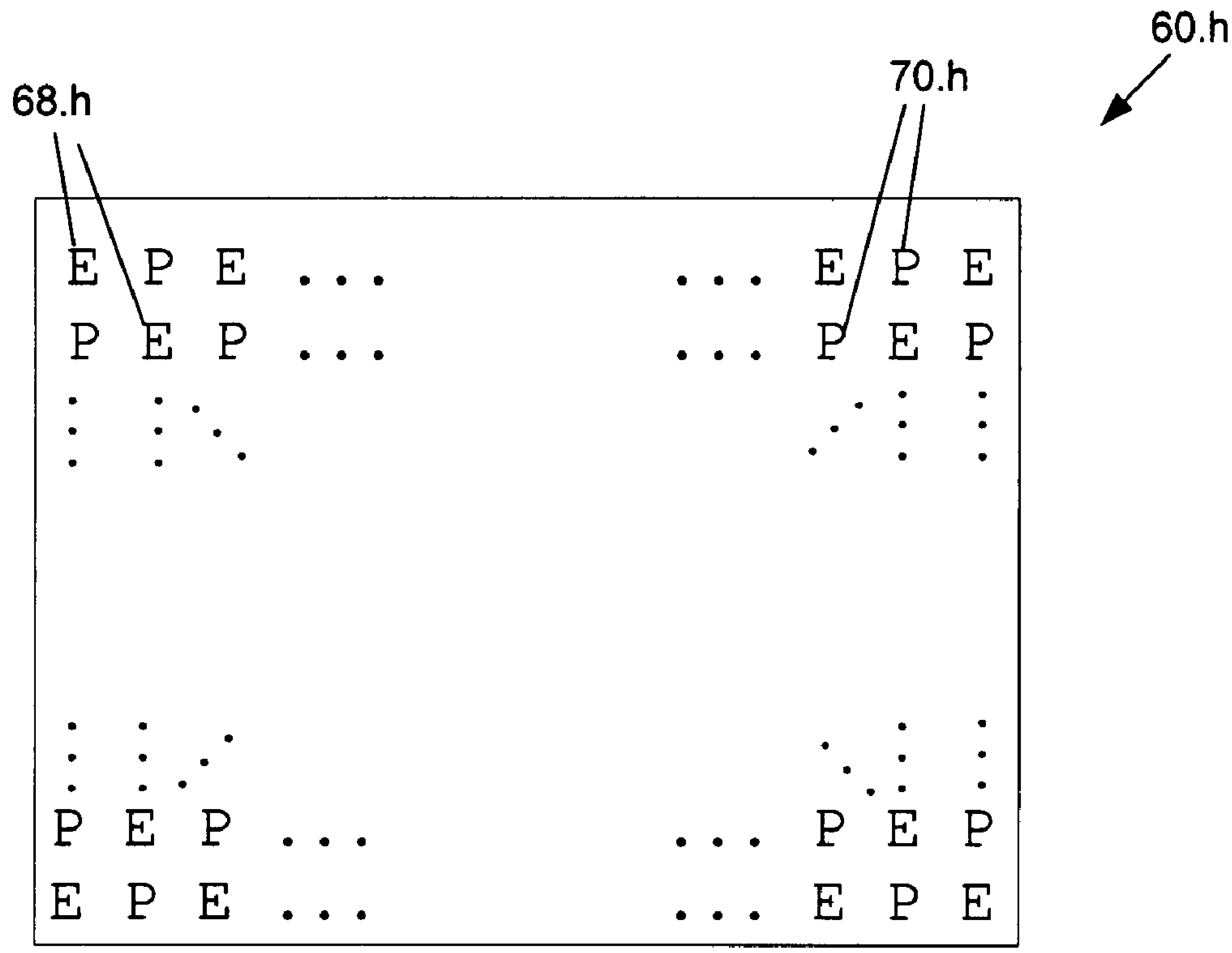


Figure 4h

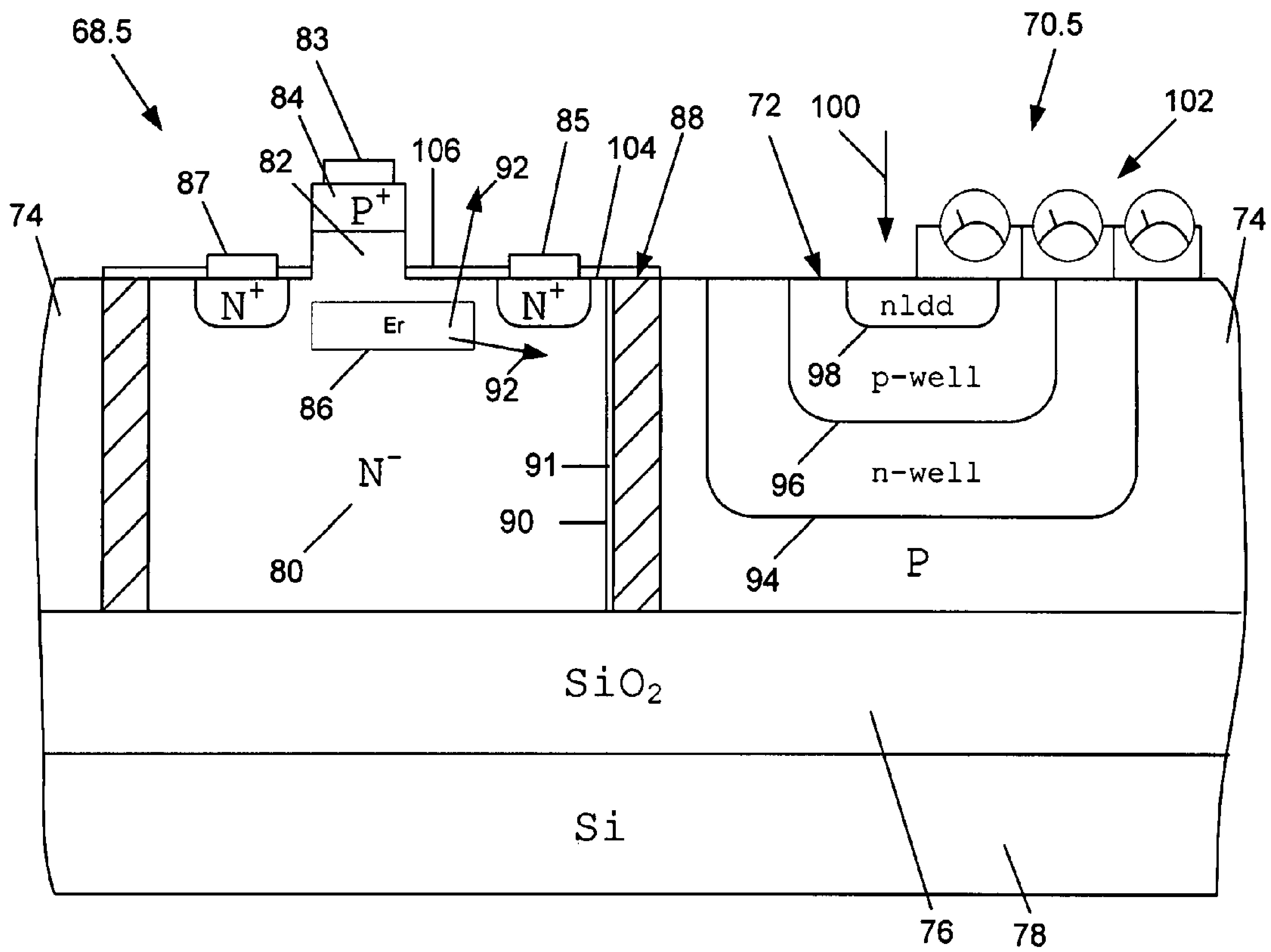
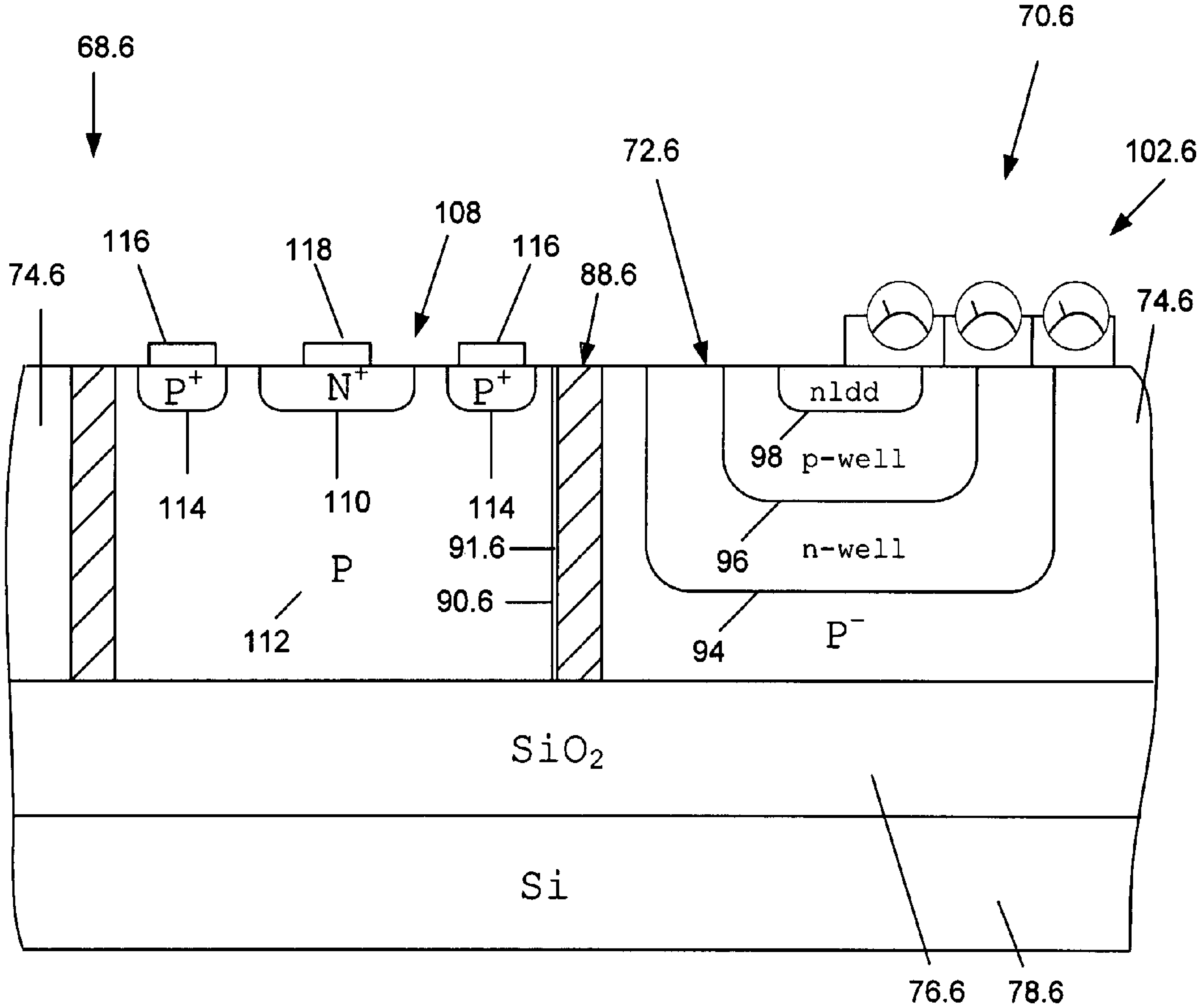

68.5
83
84
82
87
74
106
92
85
104
88
72
100
70.5
102
74
P+
N+
Er
N+
nldd
98
p-well
86
92
96
n-well
91
N-
90
80
94
P
SiO2
Si
76
78

Figure 5



68.6
70.6
102.6
72.6
108
116
118
116
74.6
88.6
74.6
P+
N+
P+
nldd
98
p-well
114
110
114
91.6
96
n-well
P
90.6
112
94
P-
SiO2
Si
76.6
78.6

Figure 6

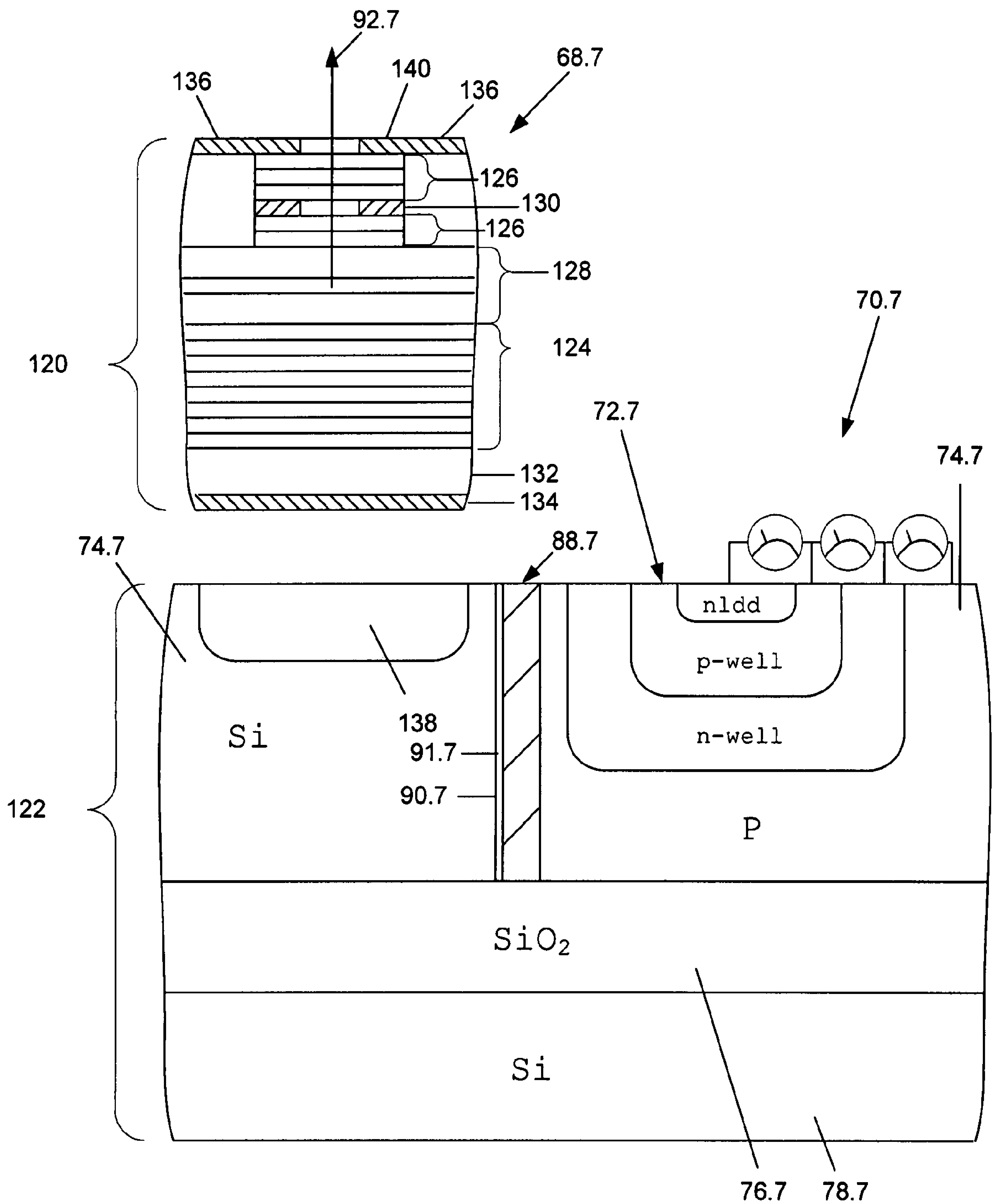

92.7
68.7
136
140
136
126
130
126
128
70.7
120
124
72.7
74.7
132
134
74.7
88.7
nldd
p-well
n-well
Si
138
91.7
90.7
122
P
SiO_2
Si
76.7
78.7

Figure 7

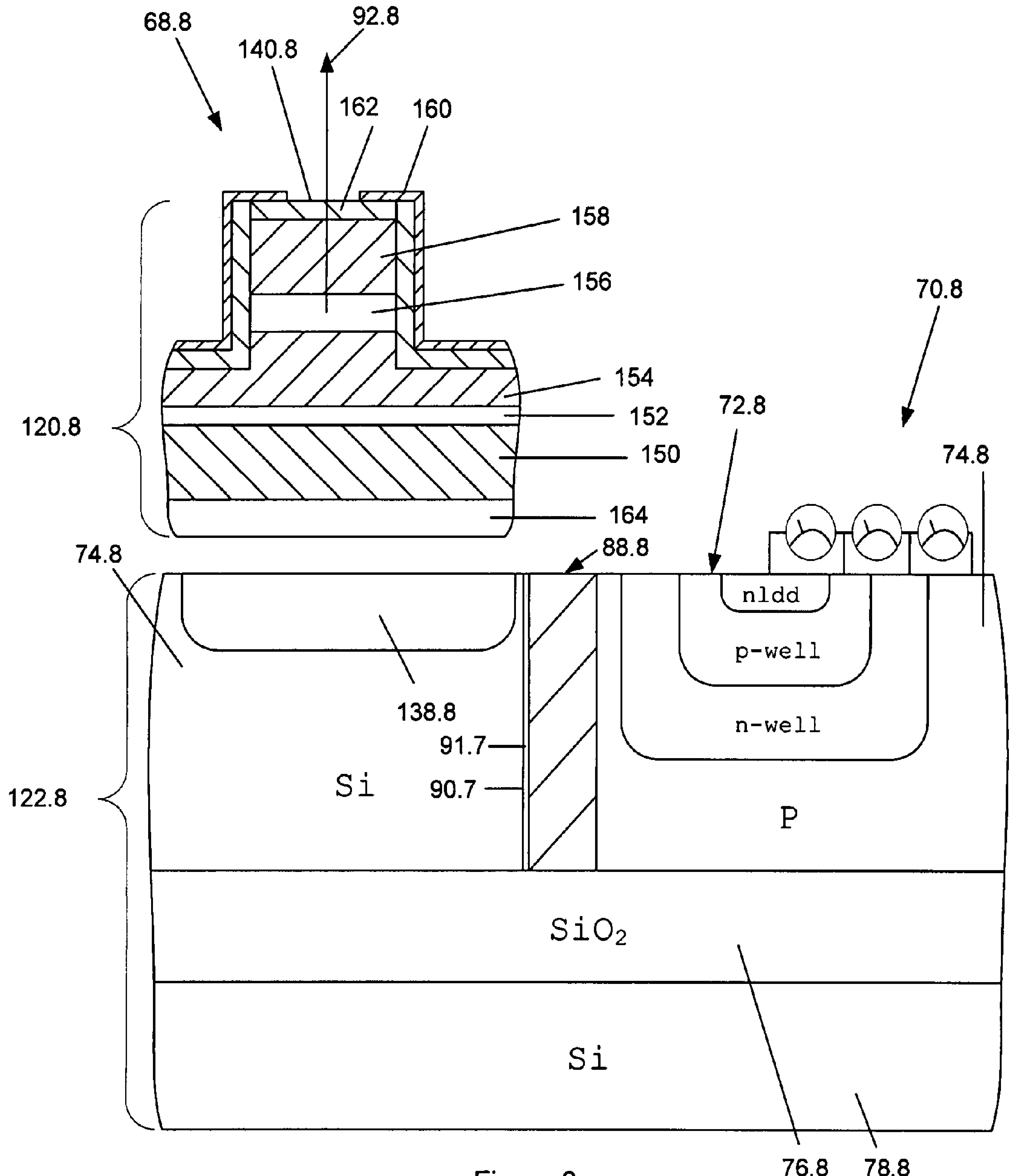
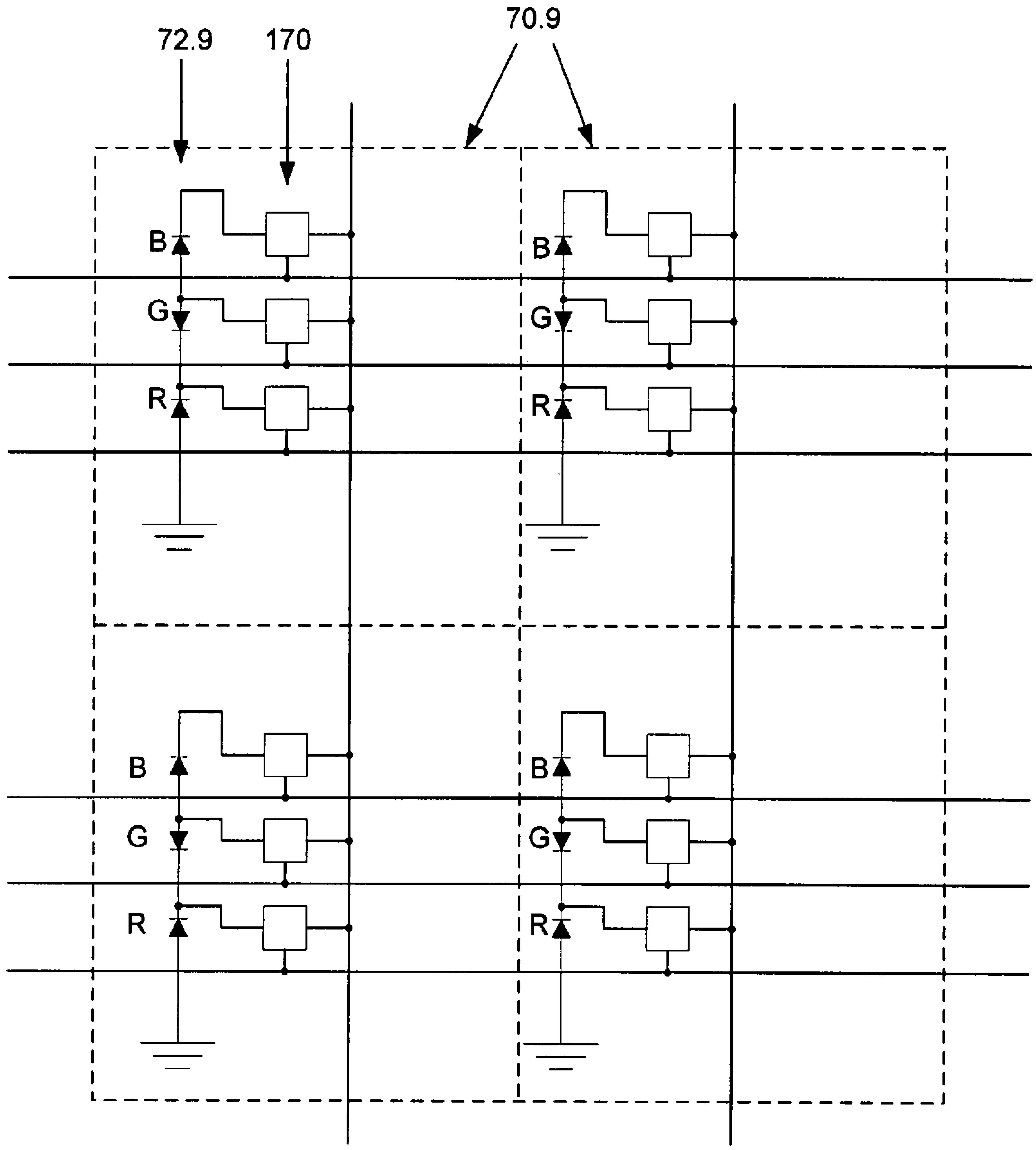
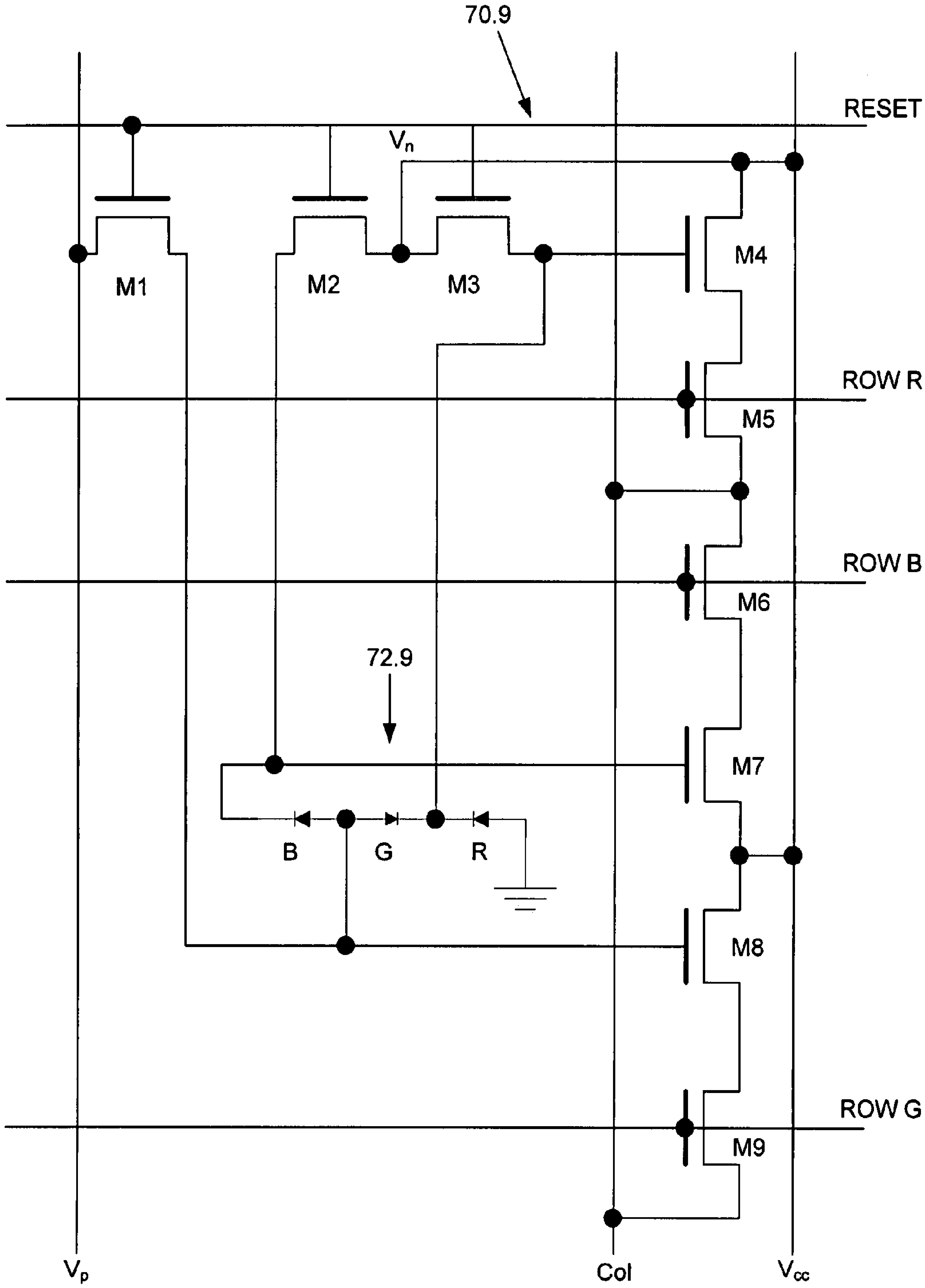

68.8
92.8
140.8
162
160
158
156
70.8
154
152
72.8
120.8
150
74.8
164
74.8
88.8
nldd
p-well
138.8
n-well
91.7
90.7
Si
122.8
P
SiO_2
Si
76.8
78.8

Figure 8



Prior Art

Figure 9



Prior Art

Figure 10

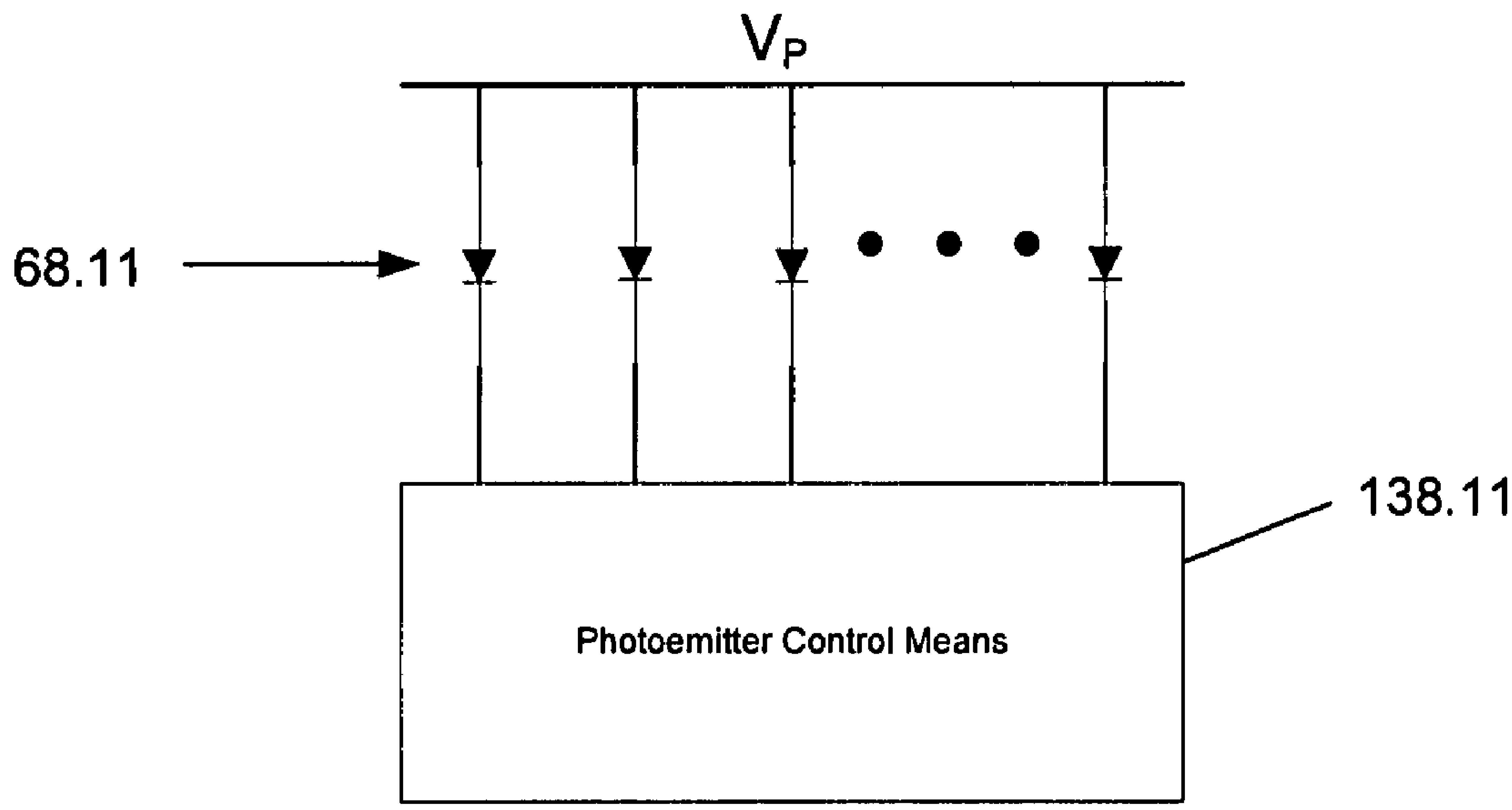


Figure 11a

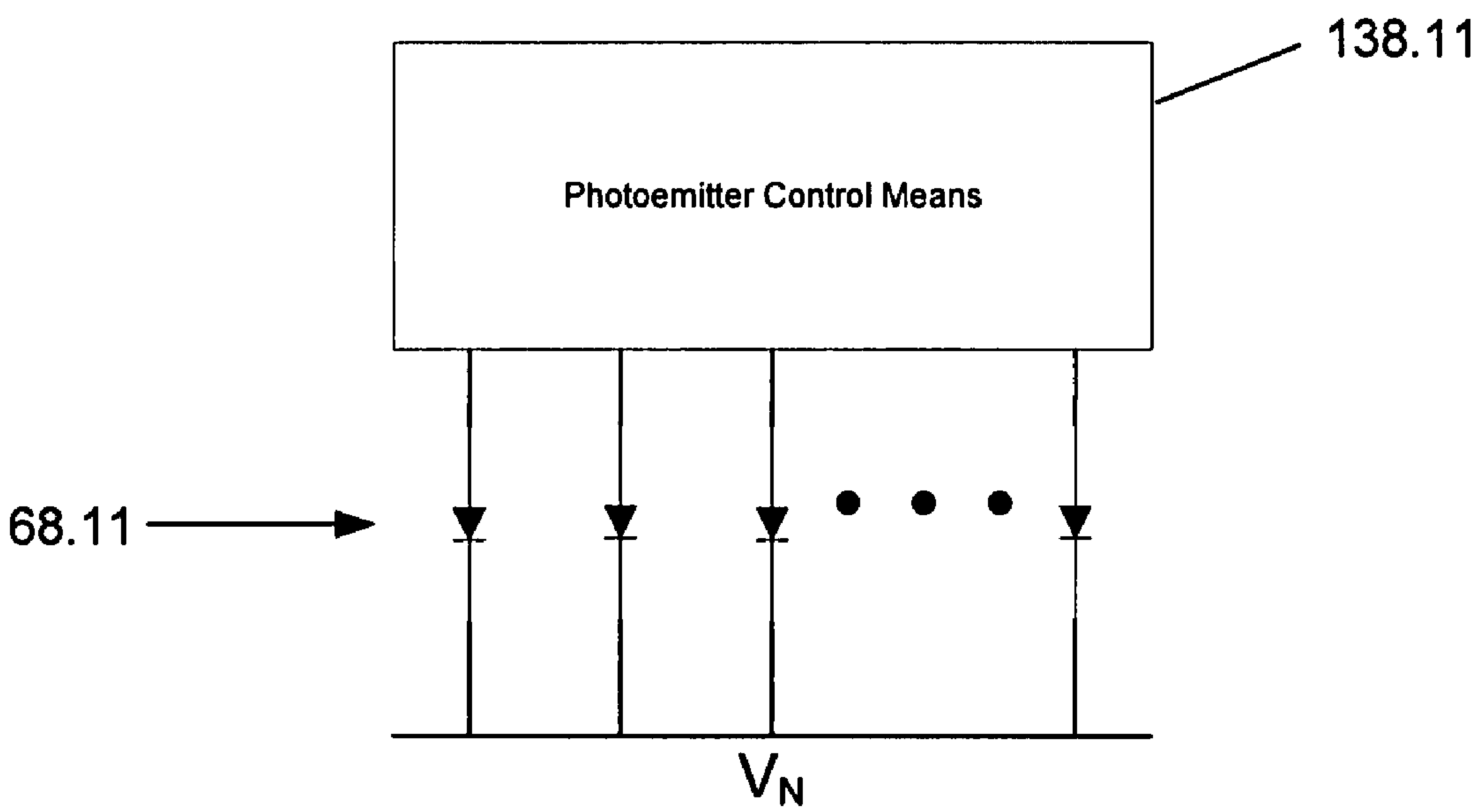


Figure 11b

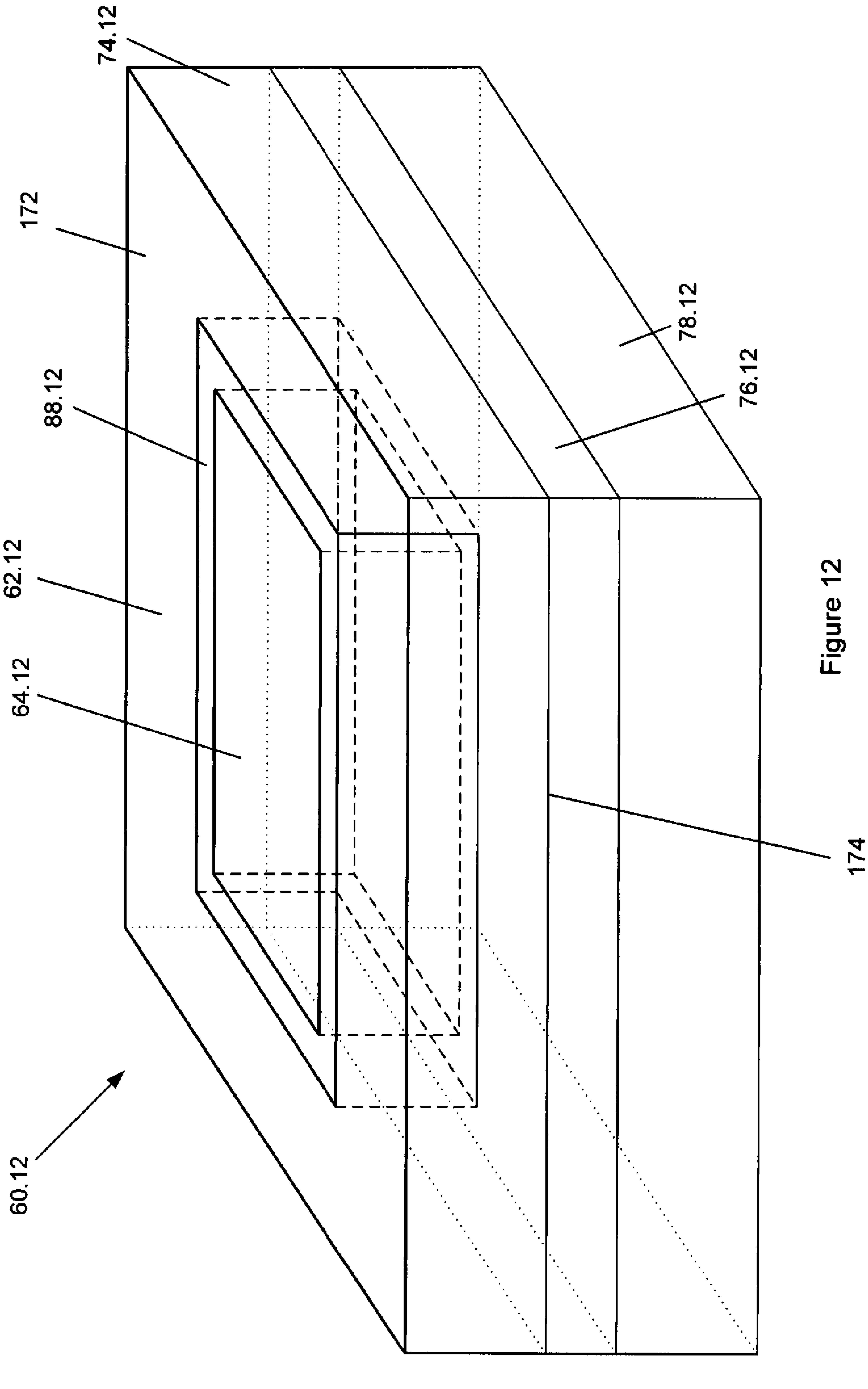


Figure 12

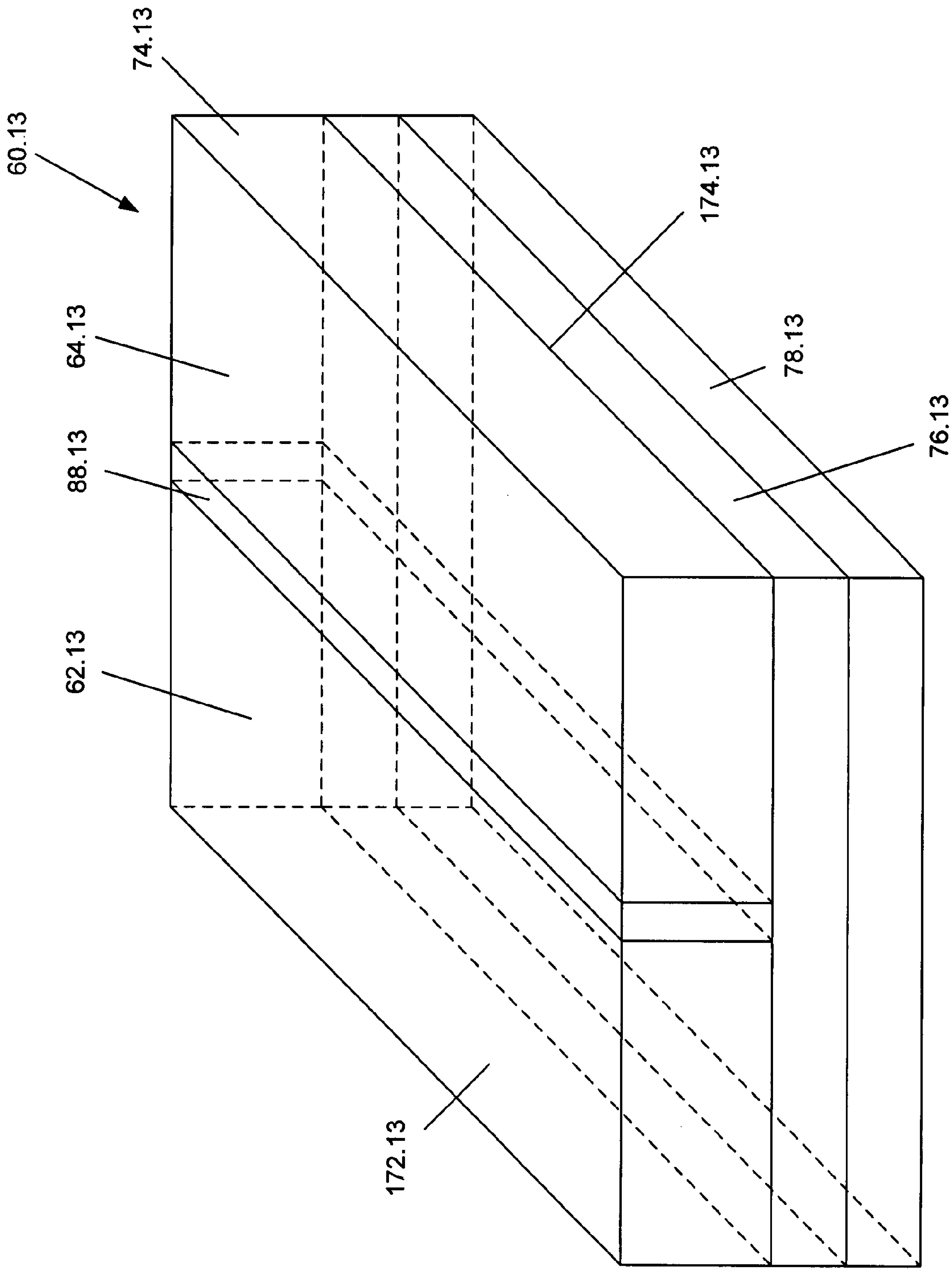


Figure 13

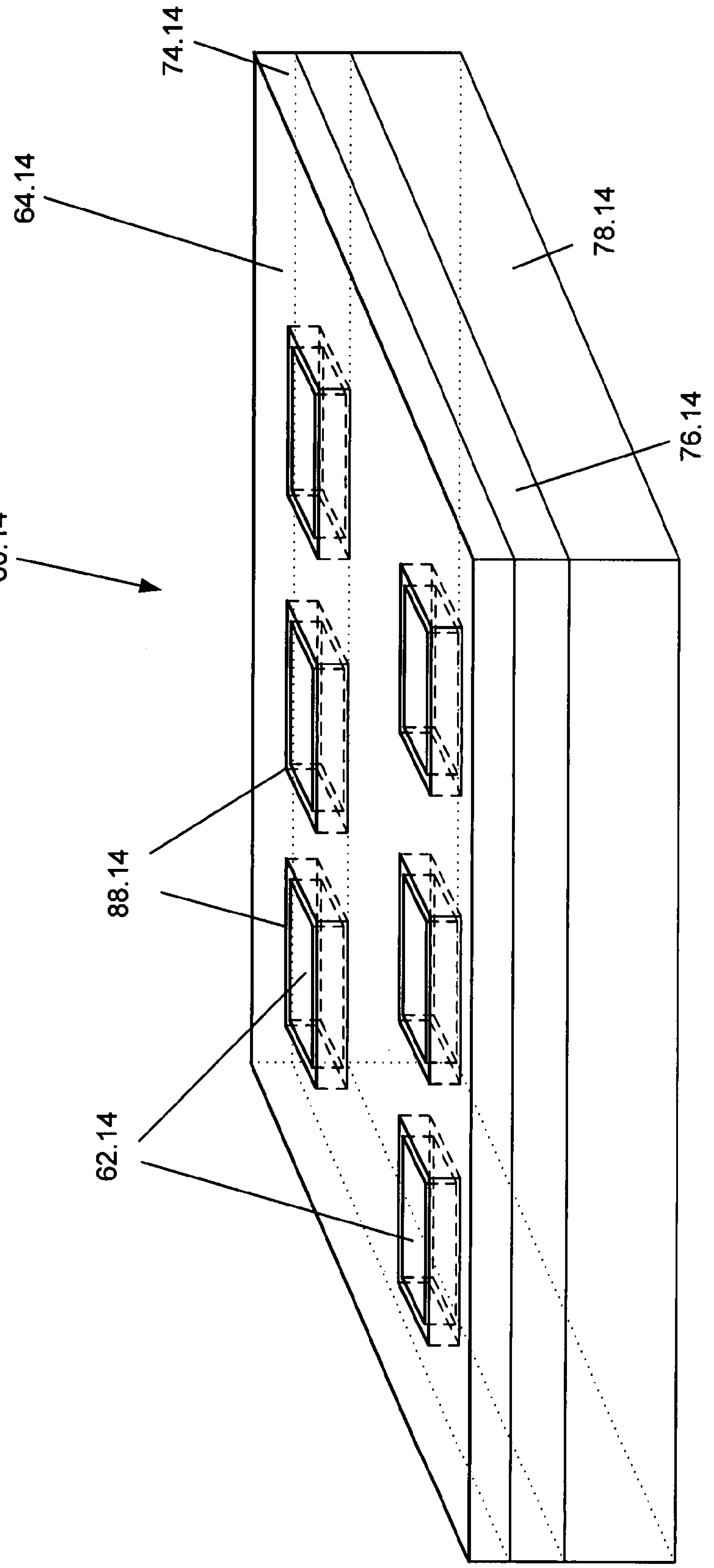


Figure 14

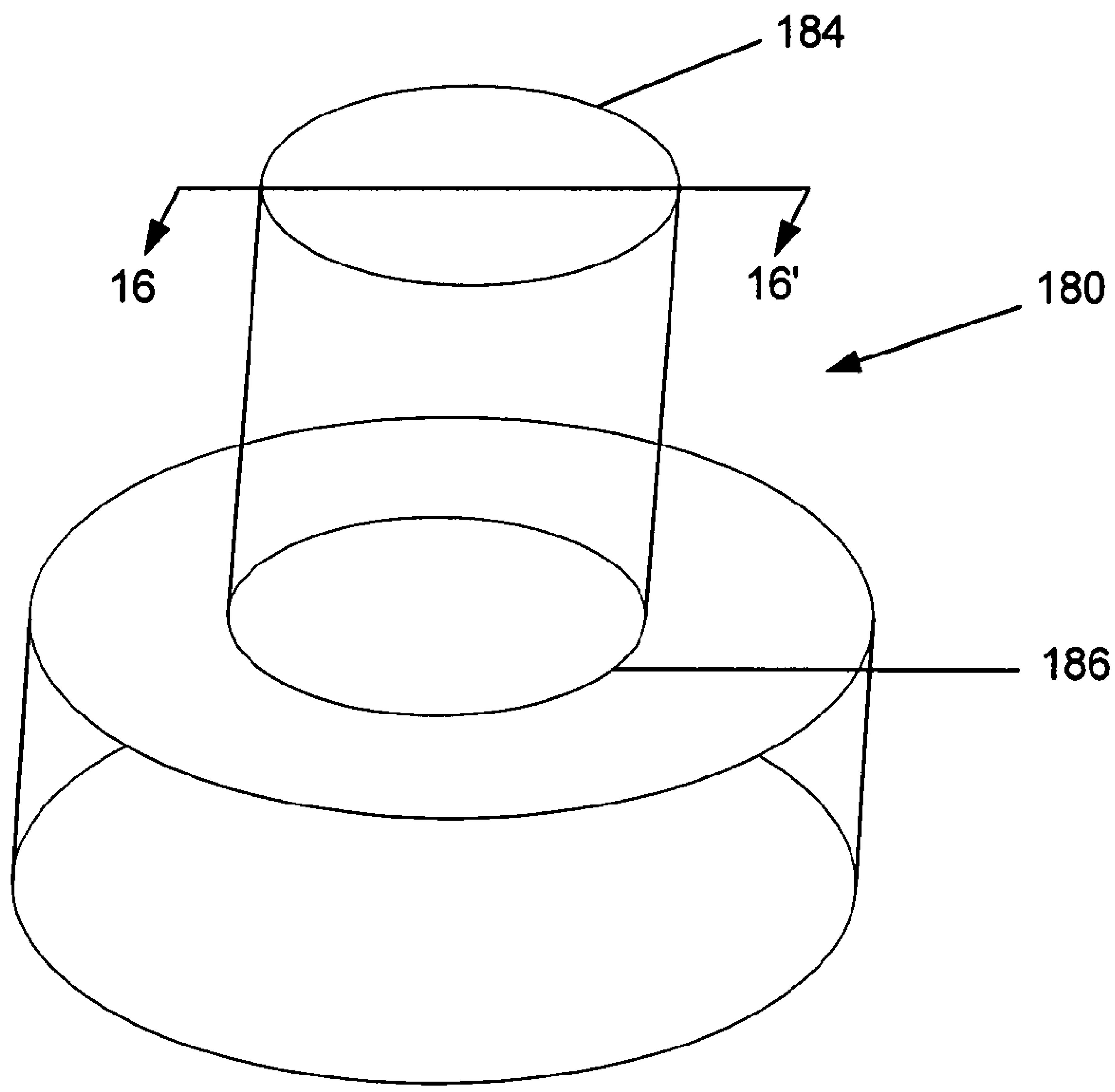


Figure 15

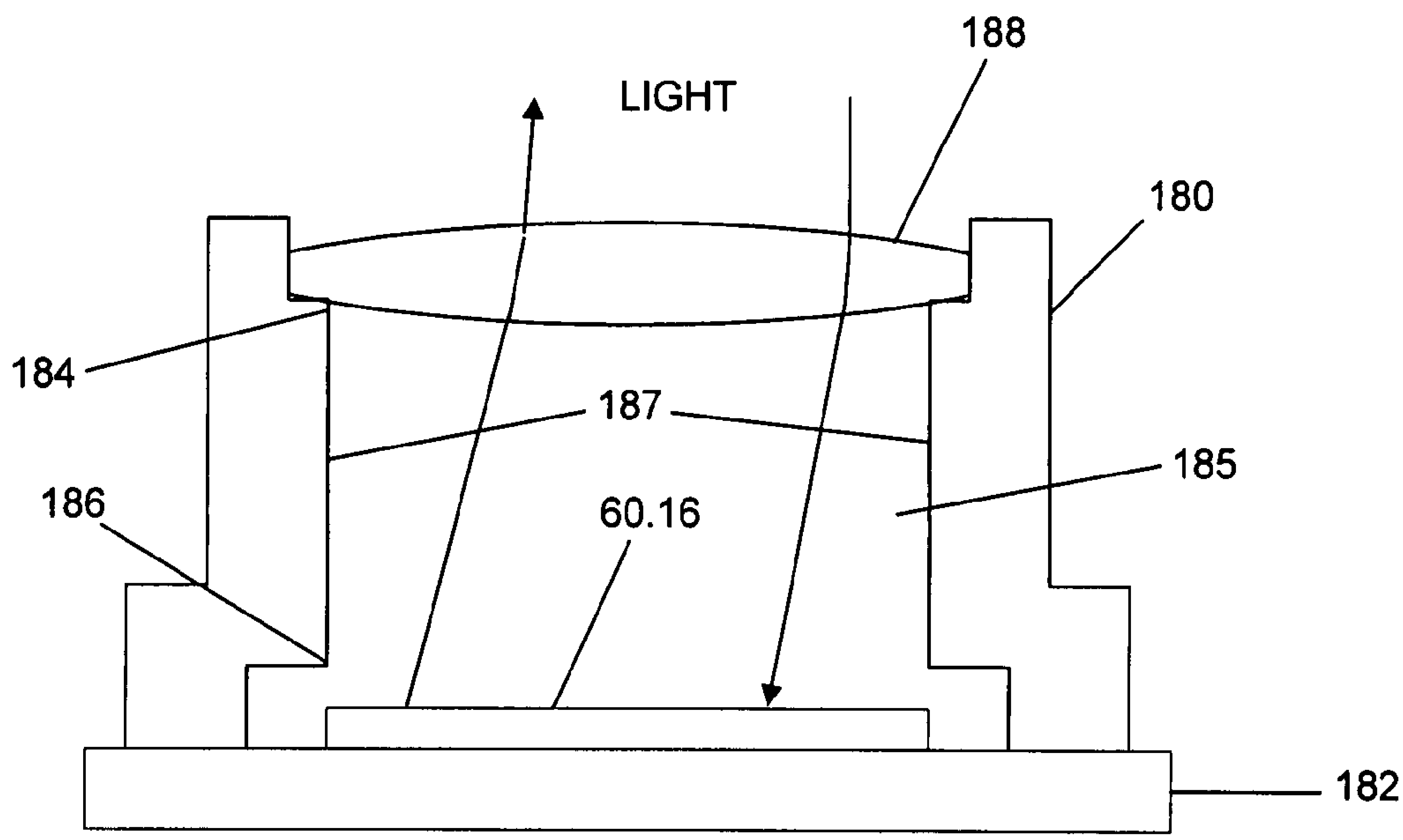


Figure 16

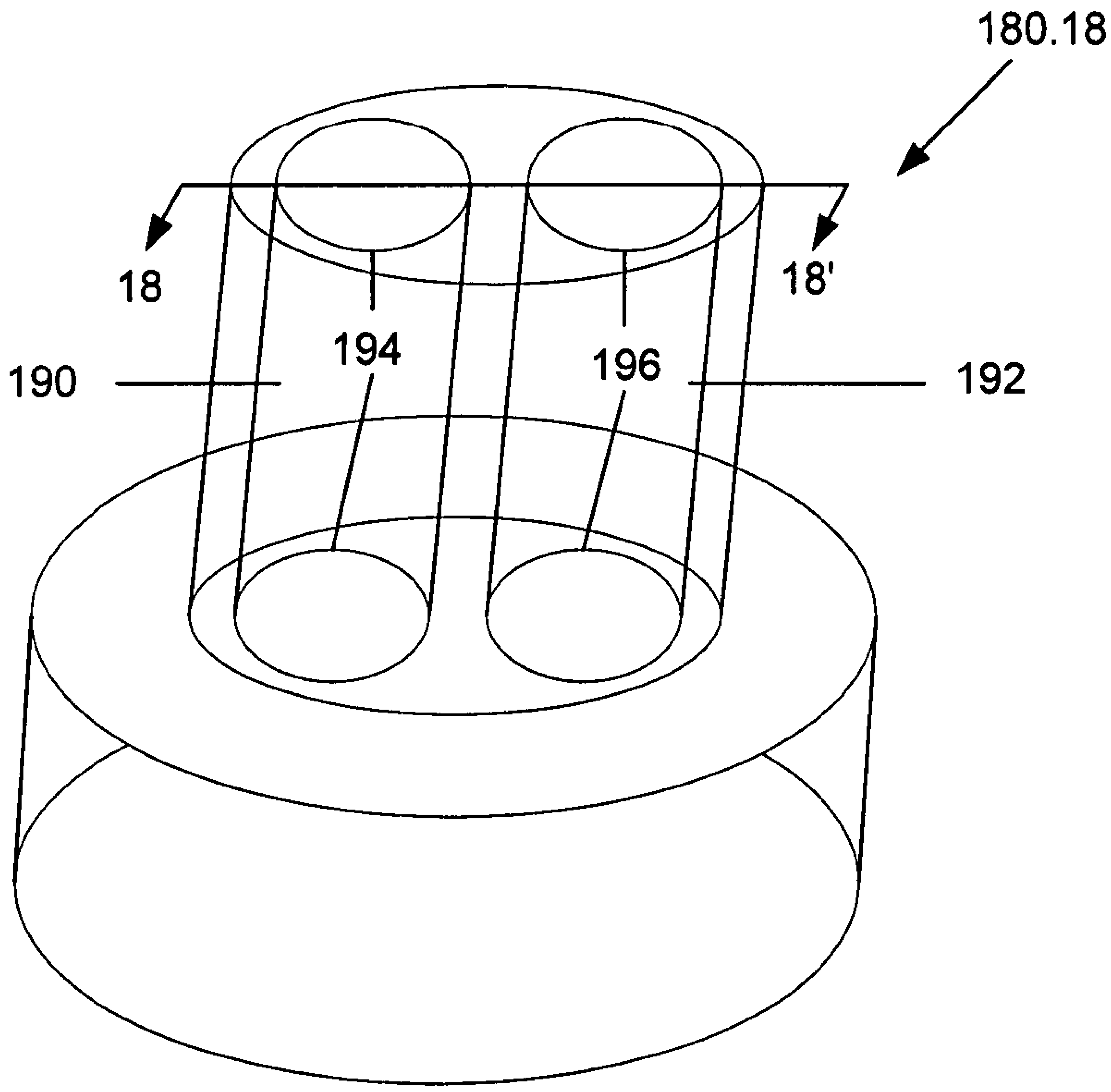


Figure 17

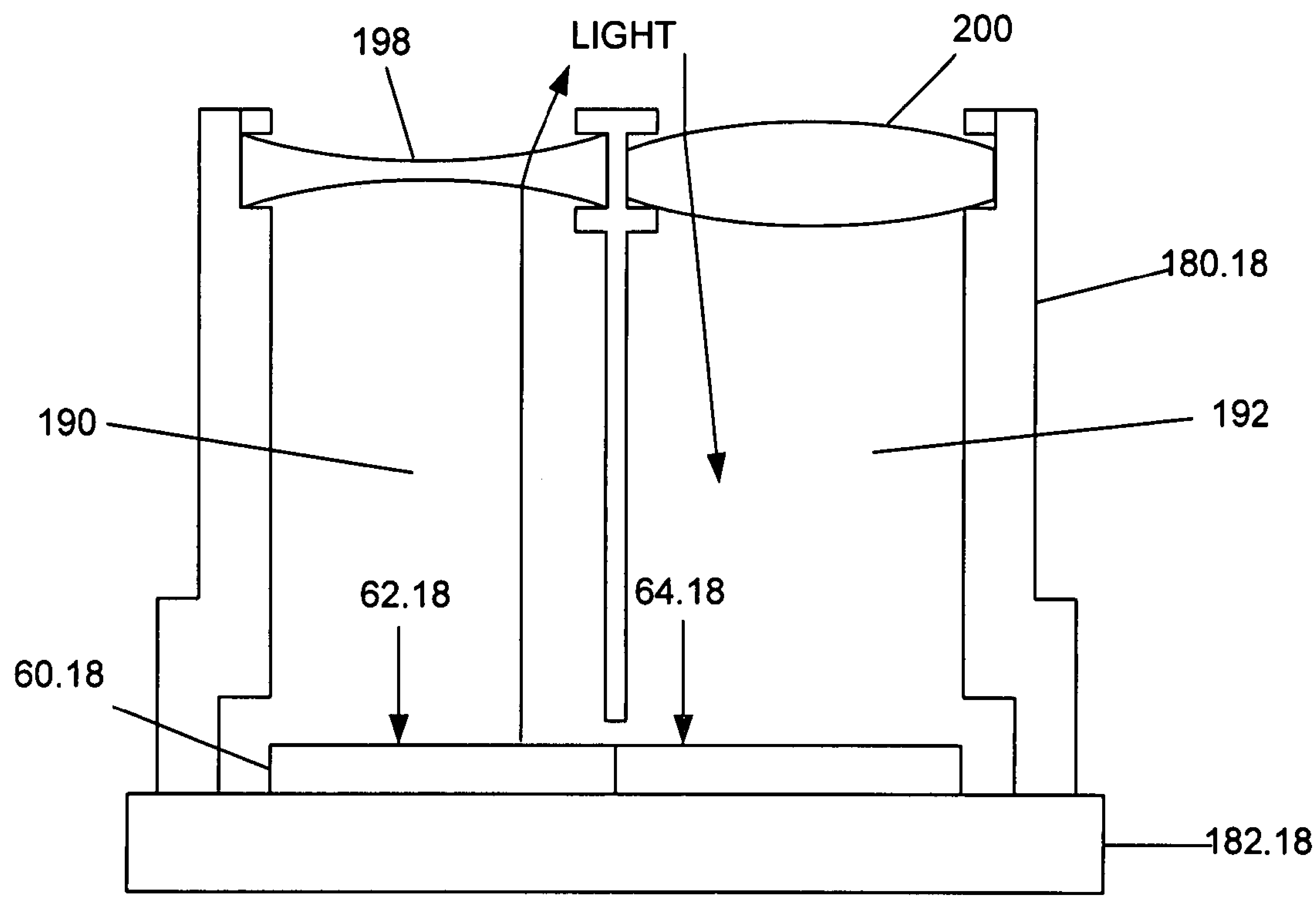


Figure 18

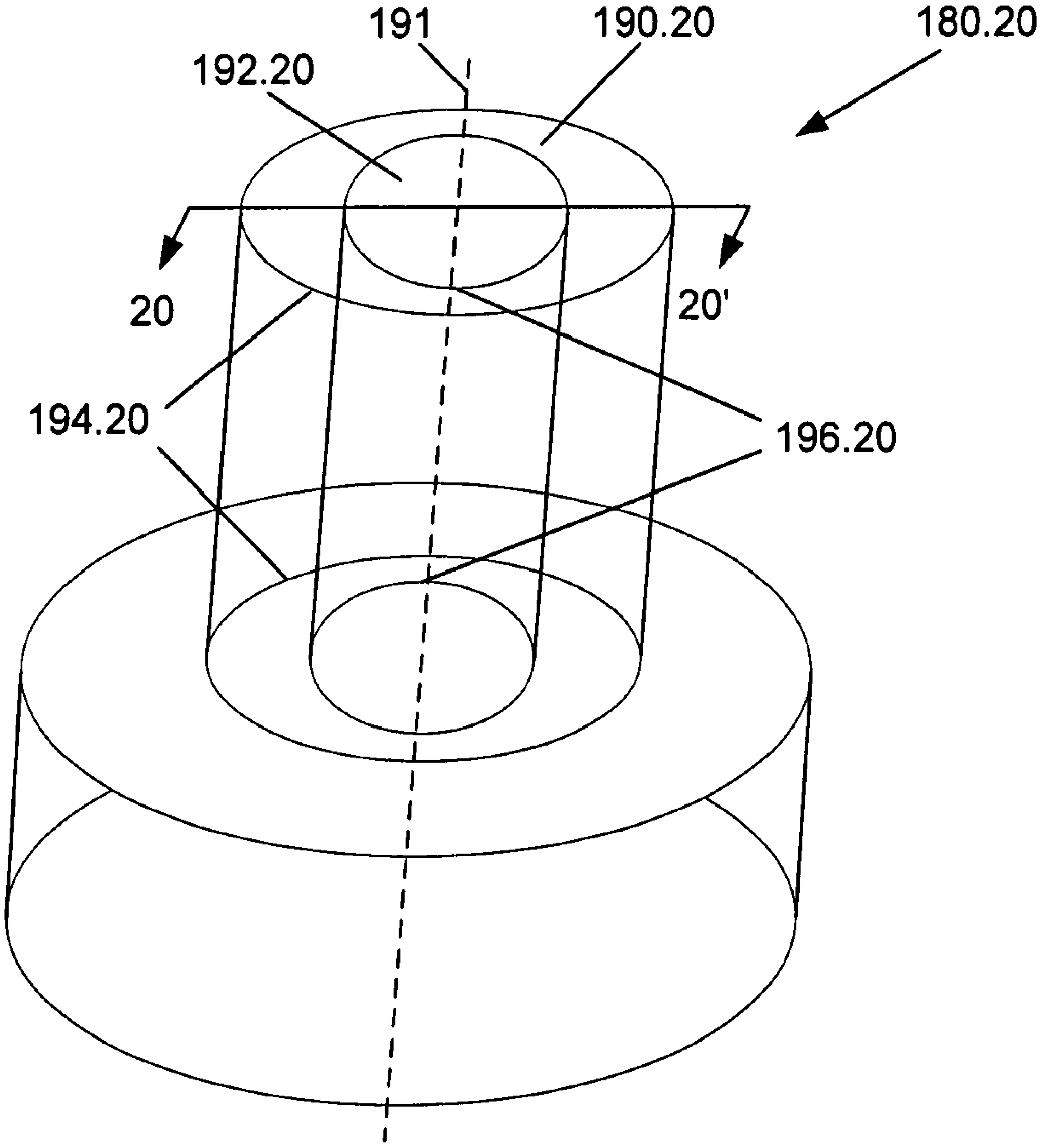


Figure 19

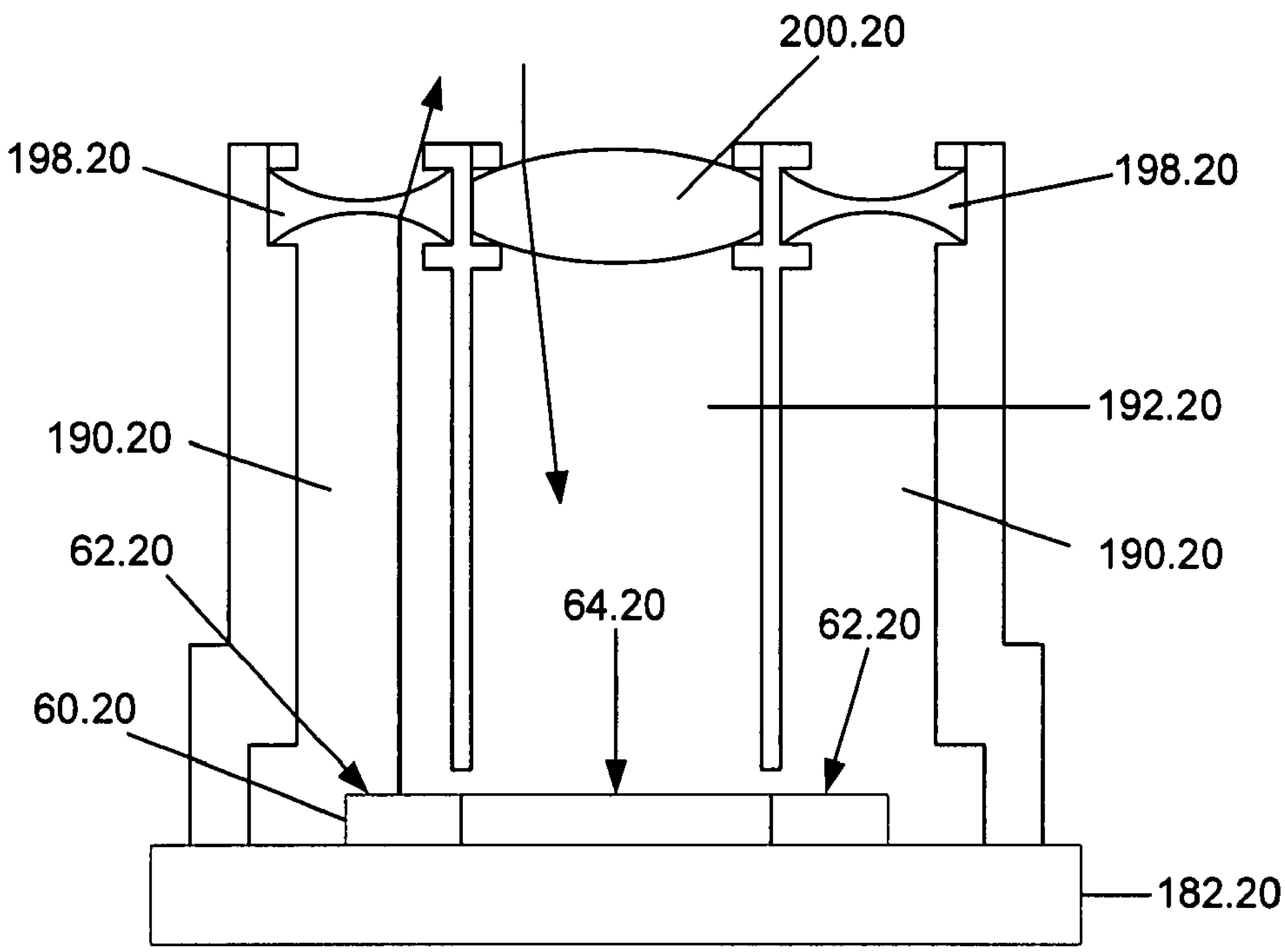
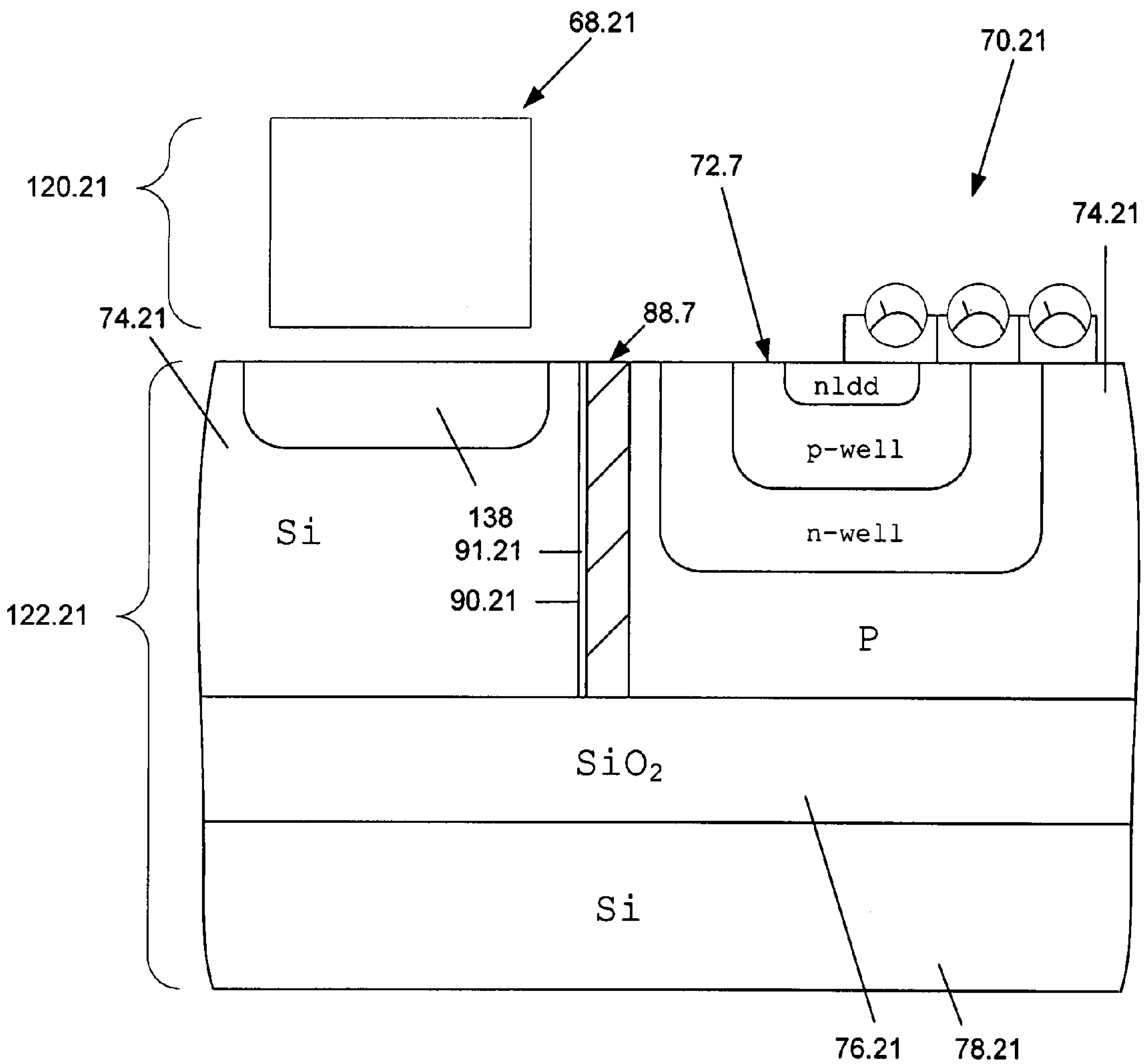


Figure 20



68.21
70.21
120.21
72.7
74.21
74.21
88.7
nldd
p-well
n-well
Si
138
91.21
90.21
122.21
P
SiO2
Si
76.21
78.21

Figure 21

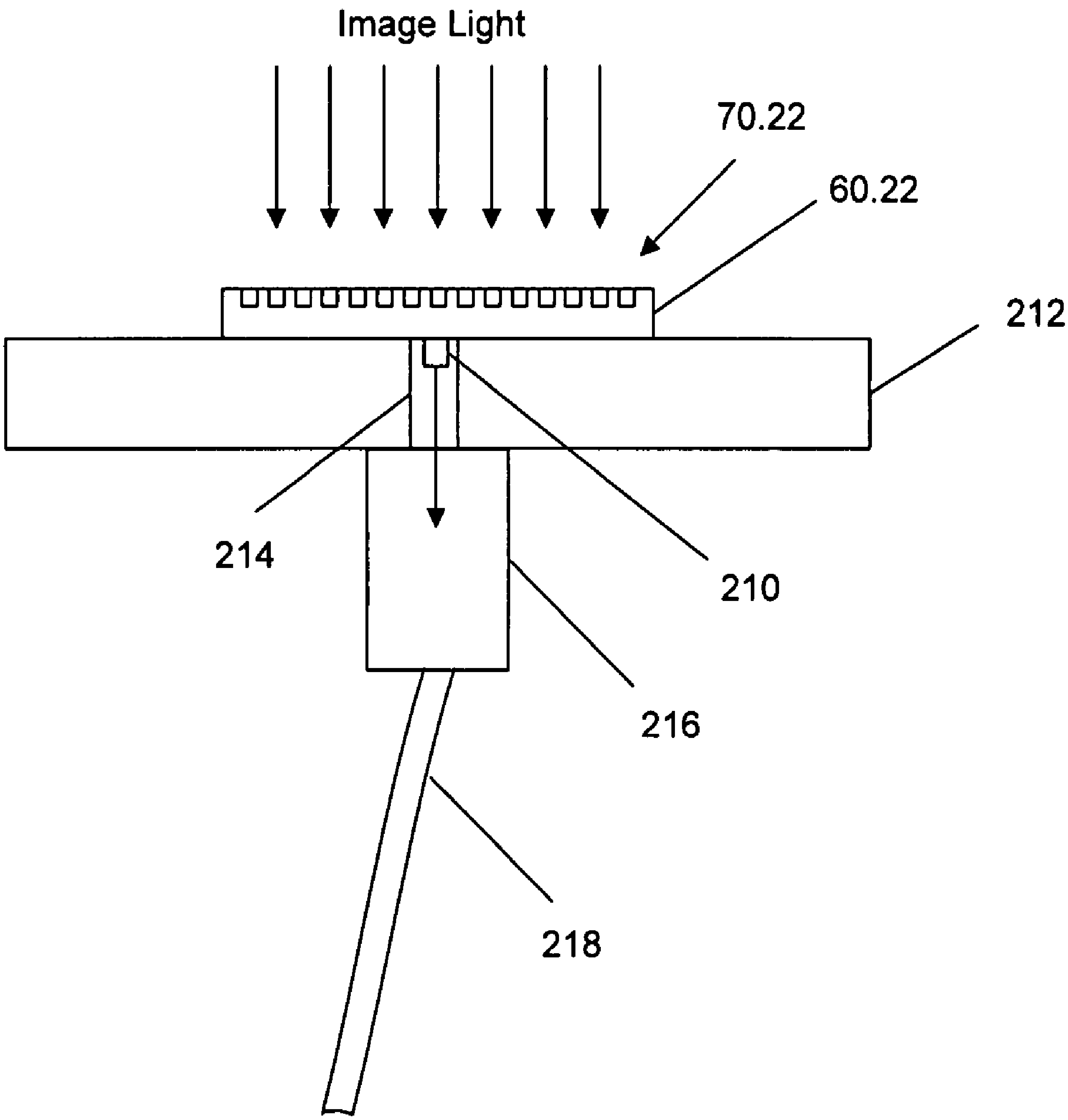


Figure 22

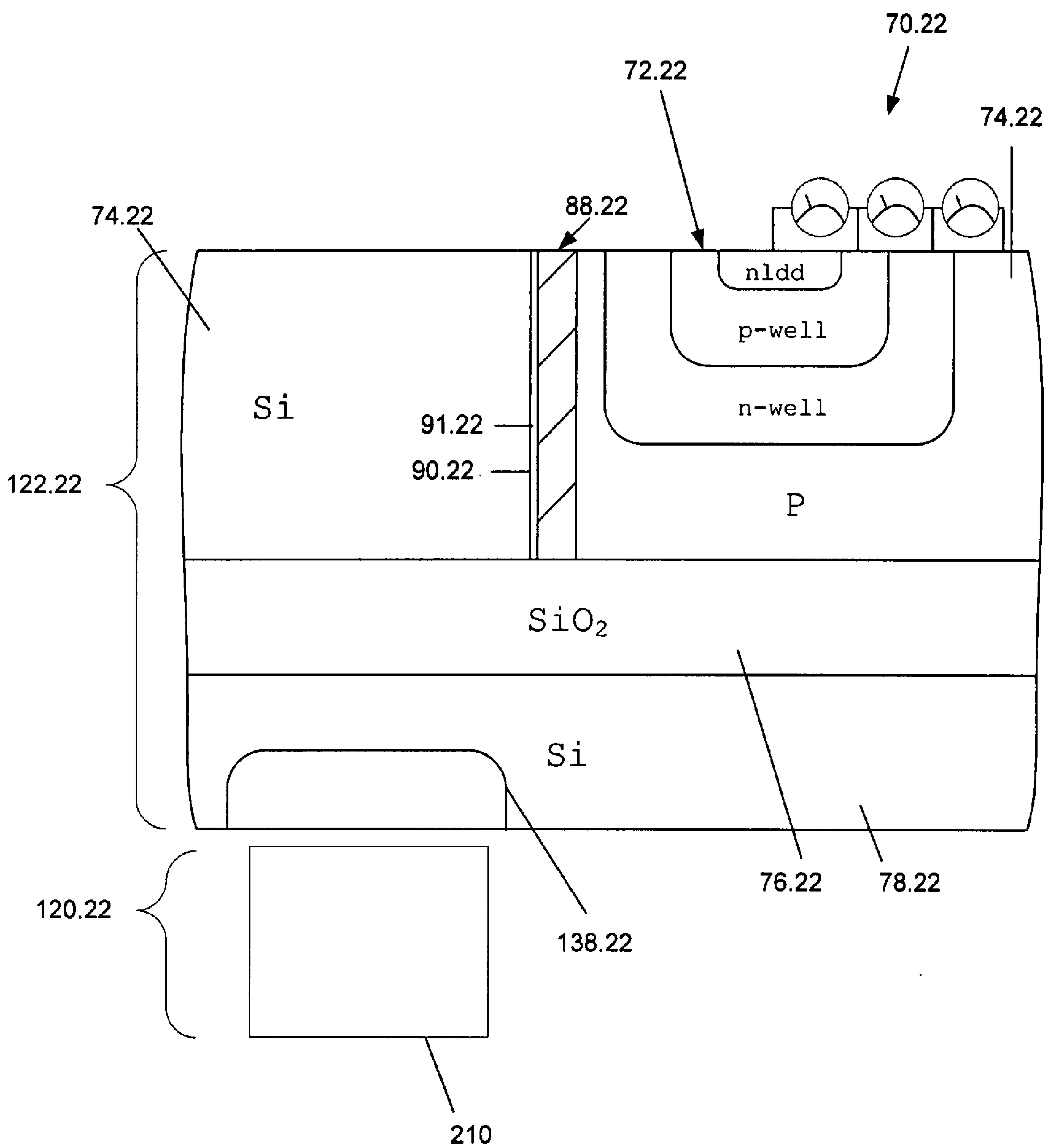

70.22
72.22
74.22
74.22
88.22
nldd
p-well
n-well
Si
91.22
90.22
122.22
P
SiO_2
Si
76.22
78.22
120.22
138.22
210

Figure 23

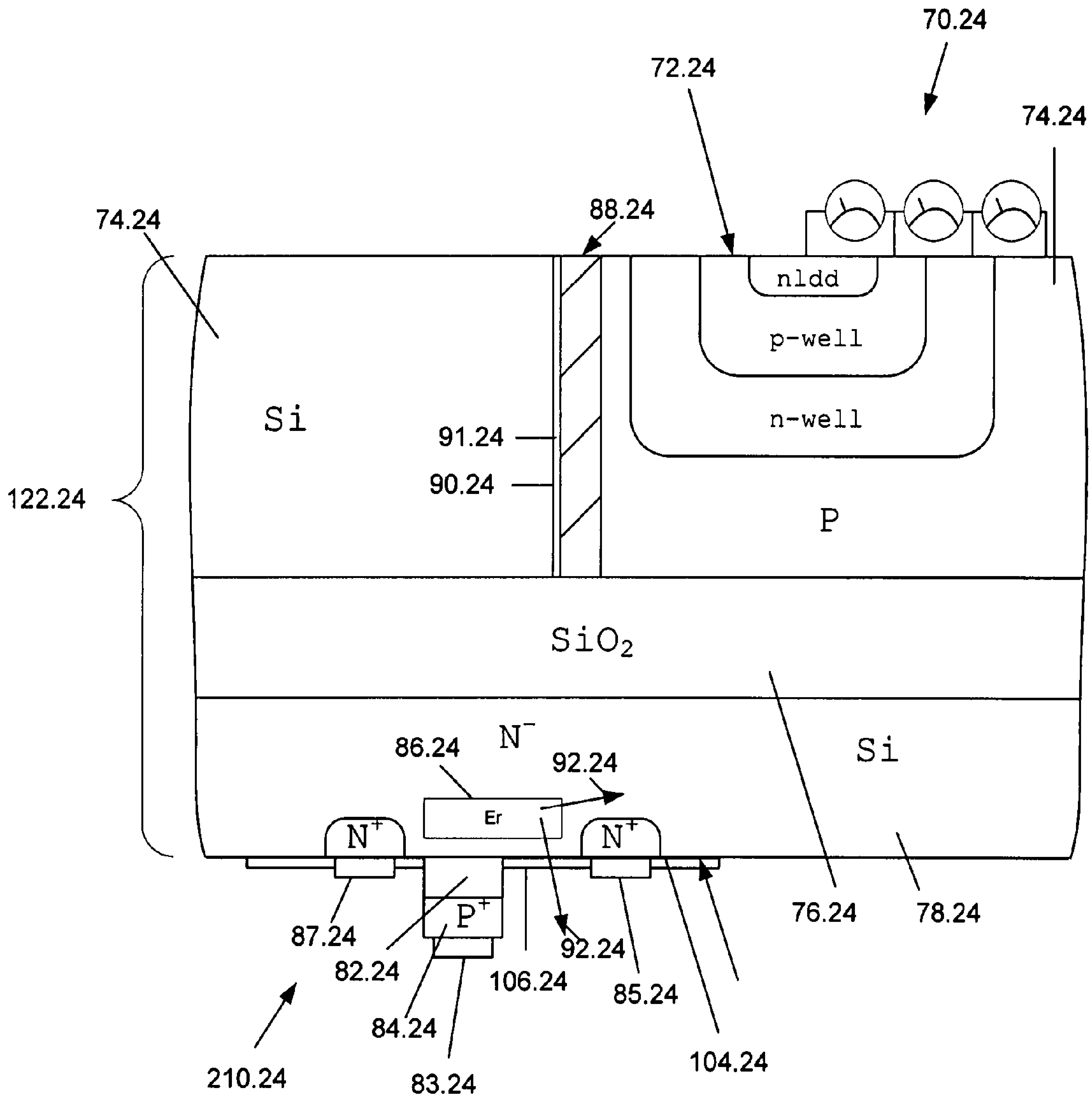

70.24
72.24
74.24
88.24
nldd
p-well
n-well
Si
91.24
90.24
122.24
P
SiO_2
N^-
86.24
92.24
Er
N^+
87.24
82.24
P^+
106.24
85.24
84.24
104.24
76.24
78.24
210.24
83.24

Figure 24

LIGHT EMITTING AND IMAGE SENSING DEVICE AND APPARATUS

RELATED APPLICATION

This application is a continuation-in-part application of U.S. Pat. application Ser. No. 10/917,377, filed Aug. 13, 2004 now U.S. Pat. No. 7,242,027 having first named inventor Paul Steven Schranz, and claims the priority benefit thereof.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a novel image sensor device, herein referred to as a light emitting and image sensing device, and the apparatus in which it is used.

2. Description of the Related Art

An embodiment of a conventional image sensor, in this case a CMOS image sensor, is schematically illustrated in cross-section in FIG. **1**. A microlens **30** focuses incident light, or photons **32**, on a plurality of photodiodes **34** in a silicon substrate **36**. Color filters **38** filter photons of specific wavelengths so that each of the photodiodes **34** collects photons within one of three ranges of wavelengths, corresponding to red, green and blue light.

An embodiment of a conventional active pixel element in a CMOS image sensor is illustrated in schematic view in FIG. **2**. The active pixel element comprises a photodiode and an active pixel circuit indicated generally by reference numerals **34**.**2** and **40** respectively. The photodiode **34**.**2** provides a photosensor signal on conductor **42**. The photosensor signal on conductor **42** is read out through a buffer transistor **44** onto a column bus **46** when a row select transistor **48** is activated. A reset transistor **50** operates to reset the photodiode **34**.**2** to a known state.

A schematic plan view of the conventional image sensor is illustrated in FIG. **3**. The conventional image sensor comprises a matrix of rows and columns of pixel elements indicated generally by reference numeral **52**. Each of the pixel elements contains a photosensing structure and corresponding support circuitry, such as the photodiode **34**.**2** and active pixel circuit **40**, respectively, illustrated in FIG. **2**.

There are many image sensor applications wherein a light source is required to illuminate a scene, or an object, so that the image sensor can capture one or more images. Examples of such applications include but are not limited to video surveillance, cell phones, digital cameras and digital video systems. During low ambient light level conditions the light source is necessary for an image to be captured at all.

An example of a conventional infrared video surveillance camera is given by U.S. Pat. No. 6,642,955 by Brent Midgley et al. Midgley describes a CCD type image sensor in a camera system that switches electronically between infrared radiation sensing and visible light sensing depending on ambient conditions. Furthermore, the camera in Midgley makes use of either incandescent or LED type illuminators. These illuminators are located external to the camera system, but may be in a camera system enclosure along with the CCD image sensor.

An example of a CMOS sensor used in cell phone is given by U.S. Pat. No. 6,730,900 by Hsish et al. in which is described a novel CMOS based active sensor array that, along with focusing optics, is preferably incorporated into a cellular phone camera for producing electronic images.

A disadvantage of the prior art is the lack of integration of a light source for image illumination with the image sensor. This has resulted in excessively large image sensor products for the applications listed above. In the case of the video surveillance camera, the illuminator is either in a separate enclosure altogether, or is mounted inside the camera system enclosure thereby increasing the size.

Another disadvantage of the lack of integration is the inability to take advantage of an illumination apparatus. In a cell phone, for example, where space is a constrained, it is often not feasible to include the illumination apparatus. In this situation, a cell phone camera can only be used in conditions where ambient light is sufficient for its operation.

Furthermore, another disadvantage of the prior art is that by lack of integration the power consumption of the above mentioned products and applications is excessively large.

BRIEF SUMMARY OF INVENTION

In one aspect of the present invention there is provided a light emitting and image sensing device for a scene. The device is formed in a semiconductor substrate and comprises a photosensor component for sensing an image of the scene. The photosensor component is responsive to incident light from the scene and provides an electrical signal representative of the image. There is also a photoemitter component for emitting a light signal representative of the electrical signal, and a coupling component connecting the photosensor component with the photoemitter component.

In another aspect of the present invention there is provided a light emitting and image sensing device for a scene. The light emitting and image sensing device is formed in a semiconductor substrate and comprises a photoemitter means for illuminating the scene with light, and a photosensor means for sensing an image of the scene. The photosensor means is responsive to incident light from the scene.

In another aspect of the invention there is provided a light emitting and image sensing device that includes a photosensor means. The photosensor means comprises a matrix of rows and columns of photosensor structures responsive to incident light upon the light emitting and image sensing device. For each row in the matrix there is row select circuitry connected to each of the photosensor structures in the row for selectively designating for outputting output signals representative of the light sensed by the photosensor structure. For each column in the matrix there is column select circuitry connected to each of the photosensor structures in the column for selectively designating for outputting output signals representative of the light sensed by the photosensor structures.

In another aspect of the invention there is provided a light emitting and image sensing device having a photoemitter means. The photoemitter means includes an array of photoemitter structures operable to emit light from the device and a photoemitter control means for controlling an emission of the light from the array of photoemitter structures.

In another aspect of the invention there is provided a light emitting and image sensing device having a photosensor means. The photosensor means comprises a plurality of select lines, a plurality of signal lines, and a plurality of pixel elements. The pixel elements include a photosensor structure, and a switching means coupled between the photosensor structure and one of the plurality of signal lines. The switching means is responsive to select signals on one or more of the plurality of select lines for conveying a photosensor signal between the photosensor structure and the one of the plurality of signal lines.

In another aspect of the present invention there is provided a light emitting and image sensing device for a scene. The light emitting and image sensing device includes a photosensor means for sensing an image of the scene and a photoemitter means for illuminating the scene with light. The photosensor means is formed in a first semiconductor substrate and is responsive to incident light from the scene. The photoemitter means is formed in a second semiconductor substrate. The second semiconductor substrate is attached to the first semiconductor substrate.

In another aspect of the present invention there is provided a light emitting and image sensing device for a scene. The light emitting and image sensing device includes a photosensor means for sensing an image of the scene and a photoemitter means for illuminating the scene with light. The photosensor means is formed in a first semiconductor substrate and is responsive to incident light from the scene. The photoemitter means is formed in a second semiconductor substrate. The second semiconductor substrate is attached to the first semiconductor substrate. The light emitting and image sensing device further includes a photoemitter control circuit operable to control an emission of the light from the photoemitter means. The photoemitter control circuit is formed in the first semiconductor substrate.

In another aspect of the present invention there is provided a light emitting and image sensing device for a scene. The light emitting and image sensing device includes a photosensor means for sensing an image of the scene and a photoemitter means for illuminating the scene with light. The photosensor means is formed in a first semiconductor substrate and is responsive to incident light from the scene. The photoemitter means is formed in a second semiconductor substrate. The second semiconductor substrate is attached to the first semiconductor substrate. The photosensor means includes a matrix of rows and columns of photosensor structures responsive to incident light upon the device. For each row in the matrix there is row select circuitry connected to each of the photosensor structures in the row for selectively designating for outputting output signals representative of the light sensed by said photosensor structure. For each column in the matrix there is column select circuitry connected to each of the photosensor structures in said column for selectively designating for outputting output signals representative of the light sensed by said photosensor structures.

In another aspect of the invention there is provided a light emitting and image sensing device that is formed in a semiconductor substrate. The light emitting and image sensing device comprises a photoemitter operable to emit electromagnetic radiation from the device, and a photosensor responsive to electromagnetic radiation incident upon the device.

In another aspect of the invention there is provided a lens housing for an image sensor type camera, the camera for generating an image of a scene. The lens housing comprises a first light channel for guiding an emission of light from the image sensor to illuminate the scene, and a second light channel for guiding light from the scene towards the image sensor.

In another aspect of the invention there is provided a housing for a light emitting and image sensing device. The housing comprises a first light channel for emitted light from the light emitting and image sensing device to illuminate a scene, and a second light channel for incident light from the scene towards the light emitting and image sensing device.

In another aspect of the invention there is provided a housing for a light emitting and image sensing device. The housing comprises a first light channel for emitted light from the light emitting and image sensing device to illuminate a scene, and a second light channel for incident light from the scene towards the light emitting and image sensing device. The second light channel has an outer surface. The first and second light channels have a common axis. The first light channel being formed around the outer surface of the second light channel.

In another aspect of the invention there is provided, in combination, a light emitting and image sensing device and a housing. The housing has a first end where the light emitting and image sensing device is disposed.

In another aspect of the invention there is provided a method of illuminating a scene and sensing an image. The method comprises the steps of emitting light from a light emitting and image sensing device, channelling the emitted light along a first channel, dispersing the light with a first lens towards the scene, focusing incident light from the scene with a second lens, channelling the focused light along a second channel towards the light emitting and image sensing device, and sensing the image of the scene with the focused light upon the light emitting and image sensing device.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be more readily understood from the following description of preferred embodiments thereof given, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** is a schematic view in cross-section of a conventional CMOS image sensor;

FIG. **2** is a schematic view of a conventional active pixel element;

FIG. **3** is a schematic plan view of a conventional image sensor;

FIGS. **4***a-h* are schematic plan views of embodiments of light emitting and image sensing devices;

FIG. **5** is a schematic view in cross-section of an embodiment of the light emitting and image sensing device in a silicon substrate;

FIG. **6** is a schematic view in cross-section of another embodiment of the light emitting and image sensing device in a silicon substrate;

FIG. **7** is a broken-away schematic view in cross-section of an embodiment of the light emitting and image sensing device wherein a photoemitter is in a first semiconductor substrate and a pixel element is in a second semiconductor substrate;

FIG. **8** is a schematic view in cross-section of another embodiment of the light emitting and image sensing device wherein a photoemitter is in a first semiconductor substrate and a pixel element is in a second semiconductor substrate;

FIG. **9** is a partial schematic view of a matrix of active pixel elements of the light emitting and image sensing device of FIG. **5**;

FIG. **10** is a schematic view of an active pixel element of the light emitting and image sensing device of FIG. **5**;

FIG. **11***a-b* are schematic views of embodiments of light emitting and image sensing devices wherein an array of photoemitters is connected to a photoemitter control means;

FIG. **12** is a schematic view in perspective of the light emitting and image sensing devices of the embodiments of FIGS. **4***a-c;*

FIG. **13** is a schematic view in perspective of the light emitting and image sensing devices of the embodiments of FIGS. **4***e-g;*

FIG. **14** is a partial schematic view in perspective of the light emitting and image sensing device of the embodiment of FIGS. **4***h;*

FIG. **15** is a schematic view in perspective of an embodiment of a housing for the light emitting and image sensing device of FIG. **4***h;*

FIG. **16** is a cross-sectional schematic view of an embodiment of the invention including the housing of FIG. **15** taken along line **16-16'**, the light emitting and image sensing device of FIG. **4***h*, and a substrate;

FIG. **17** is a schematic view in perspective of an embodiment of a housing having adjacent light channels;

FIG. **18** is a cross-sectional schematic view of an embodiment of the invention including the housing of FIG. **17** taken along line **18-18'**, either one of the light emitting and image sensing devices of FIGS. **4***e-g*, and a substrate;

FIG. **19** is a schematic view in perspective of an embodiment of a housing having light channels with a common axis;

FIG. **20** is a cross-sectional schematic view of an embodiment of the invention including the housing of FIG. **19** taken along line **20-20'**, either one of the light emitting and image sensing devices of FIGS. **4***a-d*, and a substrate;

FIG. **21** is a broken-away schematic view in cross-section of a light emitting and image sensing device wherein a photoemitter is in a first semiconductor substrate and a pixel element is in a second semiconductor substrate according to another embodiment of the present invention;

FIG. **22** is a side elevation view of a light emitting and image sensing apparatus according to another embodiment of the present invention;

FIG. **23** is a broken-away schematic view in cross-section of a light emitting and image sensing device of the light emitting and image sensing apparatus of FIG. **22**; and

FIG. **24** is a broken-away schematic view in cross-section of the light emitting and image sensing device of FIG. **23**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **4***a*, a light emitting and image sensing device, indicated generally by reference numeral **60**, is formed in a semiconductor and has a light emitting region **62** and an image sensing region **64**. The light emitting region **62** has a photoemitter **68**. The photoemitter **68** operates to emit light, from a surface **66**, to illuminate a scene, or an object. The emitted light is in a range of wavelengths, which can be in an infrared band, a visible light band or an ultraviolet band of the electromagnetic spectrum. Other bands of the electrical magnetic spectrum are, however, possible as well.

The image sensing region **64** has a plurality of pixel elements indicated generally by reference numeral **70**. The pixel elements **70** are responsive to incident light from the scene, or the object. Each of the pixel elements **70** provides a photosensor signal representative of the incident light in the area of the respective pixel element. The plurality of pixel elements **70** can be arranged in a matrix having rows and columns. An image sensor resolution is determined by a first number of pixel elements in each row and by a second number of pixel elements in each column.

Two further embodiments of the invention similar to the embodiment shown in FIG. **4***a* are illustrated in FIGS. **4***b* and **4***c* wherein like parts have like reference numerals with an additional suffix. The embodiment illustrated in FIG. **4***b* includes a plurality of photoemitters **68**.*b* positioned in a photoemitter region **62**.*b* around an image sensing region **64**.*b*. The embodiment illustrated in FIG. **4***c* includes a plurality of photoemitters **68**.*c* having a photoemitter density comparable to a pixel element density.

Another embodiment of the invention is illustrated in FIG. **4***d* wherein like parts have like reference numerals with an additional suffix. The light emitting and image sensing device **60**.*d* has a circular image sensing region **64**.*d* surrounded by a ring-shaped light emitting region **62**.*d*. The light emitting region **62**.*d* has a plurality of photoemitters **68**.*d*. The image sensing region **64**.*d* has a plurality of pixel elements **70**.*d*.

Three further embodiments of the invention are illustrated in FIGS. **4***e*, **4***f* and **4***g* wherein like parts have like reference numerals with an additional suffix. The embodiment illustrated in FIG. **4***e* includes a light emitting region **62**.*e* adjacent an image sensing region **64**.*e*. The light emitting region **62**.*e* includes a photoemitter **68**.*e* and the image sensing region **64**.*e* includes a plurality of pixel elements **70**.*e*. The plurality of pixel elements **70**.*e* can be arranged in a matrix having rows and columns. The embodiments illustrated in FIGS. **4***f* and **4***g* are similar to that of FIG. **4***e*, both including a plurality of photoemitters **68**.*f* and **68**.*g* respectively. The plurality of photoemitters **68**.*g* has a photoemitter density comparable to a pixel element density.

Another embodiment of the invention is illustrated in FIG. **4***h* wherein like parts have like reference numerals with an additional suffix. In this embodiment a plurality of photoemitters **68**.*h* are arranged in an alternating pattern with a plurality of pixel elements **70**.*h*. A photoemitter density can be different than a pixel element density.

Another embodiment of the invention is illustrated in FIG. **5**, wherein like parts have like reference numerals with an additional suffix. A photoemitter indicated generally by reference numeral **68.5** is separated from a pixel element indicated generally by reference numeral **70.5**. The photoemitter **68.5** and the pixel element **70.5** are formed on and in a first layer of silicon **74**. The first layer of silicon is formed on top of a silicon oxide (SiO_2) layer **76**, which is formed on top of a silicon substrate **78**.

In this embodiment the photoemitter **68.5** is similar to a semiconductor device for electro-optic applications described in European Patent EP1210752 by Coffa et al., which is incorporated by reference herein. An N^- region **80**, an N region **82** and a P^+ region **84** are formed in the silicon layer **74**, and together make a PN junction that under reverse bias emits light **92**. One skilled in the art will recognize that the PN junction is similar to a base-collector junction of a bipolar transistor having a base electrode **83**, a collector electrode **85** and an emitter electrode **87**. A rare earth ions doped region **86**, in this case Erbium, enables the PN junction to emit light **92** having a wavelength around 1.54 um. Using other rare earth ions allows light to be emitted having different wavelengths. For instance, as a non-limiting example, Terbium and Ytterbium provide light having a wavelength around 540 nm and 980 nm respectively.

A trench, indicated generally by reference numeral **88**, serves to reduce lateral light transmission from the rare earth ions doped region **86** towards the pixel element **70.5**. The trench **88** has a wall **90** upon which there is a film of silicon oxide (SiO_2) **91**. Light **92** travelling from the rare earth ions doped region **86** towards the pixel element **70.5** through the semiconductor layer **74** must cross the wall **90** and travel through the film of silicon oxide (SiO_2) **91**. The refractive index of silicon oxide (SiO_2) is less than the refractive index of silicon. This causes light incident on the wall **90** having an angle of incidence, from a normal to the wall, greater than a critical angle to undergo total internal reflection. In other embodiments multiple trenches having films of silicon oxide (SiO_2) can be used to further reduce lateral light transmission. The trench **88** has the advantage of reducing phantom images in and preventing blurring of pixel element **70.5** as caused by the above mentioned lateral light transmission.

The light **92** emitted from the rare earth ions doped region **86** has random directions. The light **92** strikes a surface **104**, defined by a boundary between the silicon layer **74** and a silicon oxide layer **106**, at various angles of incidence to a normal to the surface. Light **92** having the angle of incidence greater then the critical angle will be internally reflected. It is advantageous, then, that the light **92** be substantially normal to the surface **104** in order for maximum light emission from the surface. The goal is to maximize an external quantum efficiency, a problem well known in the art. In another embodiment, a photoemitter can be provided similar to a device presented in "Si-based Resonant Cavity Light Emitting Devices" by Castagna et al in SPIE Vol 5366, which is incorporated by reference herein. This has the advantage that light generated is substantially normal to surface **104**. This has a further advantage of reducing lateral light transmission through the semiconductor layer **74** towards the pixel element **70.5**.

The pixel element **70.5** of the present embodiment is commonly known in the prior art, as disclosed by U.S. Pat. No. 5,965,875 by Merril, which is incorporated by reference herein, and as such will not be described in great detail here. The pixel element **70.5** includes a photosensor structure **72**. The photosensor structure **72** is based on a triple well structure forming a first PN junction **94**, a second PN junction **96** and a third PN junction **98**. Incident light **100** having different wavelengths penetrates the photosensor structure **72** at varying depths depending on the wavelength. Red light penetrates to around the depth of the first PN junction **94** where it produces a red photo current. Green light penetrates to around the depth of the second PN junction **96** where it produces a green photo current. Blue light penetrates to around the depth of the third PN junction **96** where it produces a blue photo current. A photocurrent sensor indicated generally by reference numeral **102** measures the red, green and blue photocurrents.

When the incident light **100** is in the near ultraviolet and near infrared bands of the electromagnetic spectrum, the photosensor structure **72** is still capable of functioning well. A study performed by Alternate Vision Corporation indicates that the photosensor structure **72** performs well under such conditions. The results of the study were published in a paper titled "Infrared and ultraviolet imaging with a CMOS sensor having layered photodiodes" by Gilblom et al.

The pixel element **70.5** of this embodiment is advantageous since it takes less area of surface **104** to sense red, green and blue components of light **100**. This allows increased resolution for a given surface area. Nevertheless, other image sensor structures formed in silicon can be used for the present invention. This includes CMOS image sensor structures, such as in FIG. **1**, and CCD image sensor structures.

Referring now to FIG. **6**, another embodiment of the invention is illustrated wherein like parts have like reference numerals with an additional suffix. The photoemitter **68.6** is in this case formed using a PN junction diode, indicated generally by reference numeral **108**, with un-annealed implant dislocations used to enhance light emission. The structure of the PN junction diode **108** is described in great detail in U.S. Pat. No. 6,710,376 by Worley, which is incorporated by reference herein. The pixel element **70.6** is similar to the pixel element **70.5** in FIG. **5**.

The PN junction **108** is comprised of an N+ implant region **110**, in a doped P type region **112**, and a P+ implant **114** that is used to make a good electrical connection between the P-type region and metal terminals **116**. A connection is made to the N+ implant region **110** using the metal terminal **118**.

Several light emitting devices are known in the prior art that use III-V or II-VI semiconductors and compound semiconductors, for example LEDs, resonant cavity light emitting diodes (RCLED) and vertical cavity surface emitting lasers (VCSEL). It would be advantageous to include these types of devices with a silicon based image sensor.

Another embodiment of the invention is illustrated in FIG. **7** wherein like parts have like reference numerals with an additional suffix. A first semiconductor substrate **120** is illustrated above a second semiconductor substrate **122**. The first semiconductor substrate **120** is formed from III-V or II-VI compound semiconductor materials, whereas the second semiconductor substrate **122** is formed from silicon. A photoemitter **68.7** is formed in the first semiconductor substrate **120**, and a pixel element **70.7** is formed in the second semiconductor substrate **122**. The pixel element **70.7** is similar to the pixel element **70.5** in FIG. **5**.

In the present embodiment, the photoemitter **68.7** is similar to a light emitting device disclosed in U.S. Pat. 5,493,577 by Choquette et al, which is incorporated by reference herein, wherein the light emitting device has a structure compatible for both RCLEDs and VCSELs. The photoemitter **68.7** comprises a first distributed Bragg reflector (DBR) **124**, a second DBR **126**, an active region **128** and a control layer **130**. The first and second DBRs **124** and **126** and the active region **128** form a resonator, or what is commonly called a Fabry-Perot resonator. A substrate **132** attaches the first DBR **124** to a first electrode **134**. A second electrode **136** is deposited on the second DBR **126**. Choquette describes the operation of the photoemitter **68.7** for RCLED and VCSEL embodiments in great detail.

Light **92.7** is emitted substantially along an axis and normal to a surface **140**. Since the index of refraction of the second DBR **126** is greater than that of air, the surrounding environment, this has the advantage of minimizing the effects of internal reflection at the surface **140**. This increases an external quantum efficiency of the photoemitter **68.7**. Another advantage of the orientation of light **92.7** to surface **140** is that light is substantially not emitted towards the photosensor structure **72.7**. This prevents the formation of phantom images in and/or blurring of the pixel element **70.7**. In this embodiment the light **92.7** has a wavelength of 980 nm which is in the near infrared region.

The first semiconductor substrate **120** is attached to the second semiconductor substrate **122**. The first electrode **134** is operatively connected to photoemitter control circuitry **138**, which can enable, disable and control the intensity of light emission of the photoemitter **68.7**. Attaching different types of semiconductor substrates together, for instance GaAs and Si, and providing many electrical connections between them is well known in the art. The company Xanoptix Inc. provides such hybrid integrated circuit technology.

In another embodiment, a light emitting and image sensing device using a III-V compound semiconductor substrate and a silicon substrate is illustrated in FIG. **8**, wherein like parts have like reference numerals with an additional suffix. In this embodiment, the photoemitter **68.8**, again, is formed in the first semiconductor substrate **120.8**, and the pixel element **70.8** is formed in a second semiconductor substrate **122.8**. The photoemitter **68.8** is similar in structure to a VCSEL disclosed in U.S. Pat. No. 6,590,917 by Nakayama et al., which is incorporated by reference herein. The photoemitter **68.8** includes an n-type GaAs substrate **150**, an epitaxial n-type GaAs layer **152**, an n-type DBR **154**, an active layer region **156**, a p-type DBR **158**, a first mode control layer **160**, a second mode control layer **162** and an electrode **164**.

The photoemitter **68.8** is similar in structure to a VCSEL disclosed in U.S. Pat. No. 6,590,917 by Nakayama et al. The photoemitter **68.8** includes an n-type GaAs substrate **150**, an epitaxial n-type GaAs layer **152**, an n-type DBR **154**, an active layer region **156**, a p-type DBR **158**, a first mode control layer **160**, a second mode control layer **162** and an electrode **164**.

Light **92.8**, again, is emitted substantially normal to a surface **140.8** having the advantage of increasing an external quantum efficiency and minimizing light emitted towards the photosensor structure **72.8**.

Referring back to FIGS. **4***a-h,* the light emitting and image sensing devices **60** and **60***b-h* include the plurality of pixel elements **70** and **70***b-h* respectively. Each one of the pixel elements **70** and **70***b-h* can be the pixel element **70.5** illustrated FIG. **5**. In another embodiment, the pixel element **70.5** illustrated in FIGS. **5**, and similarly the pixel elements **70.6**, **70.7** and **70.8** illustrated in FIGS. **6**, **7**, and **8** respectively, can be arranged in a matrix configuration as illustrated in FIG. **9**, wherein like parts have like reference numerals with an additional suffix. Four such pixel elements **70.9** are illustrated in FIG. **9** in a matrix having two rows and two columns (2×2), however, there may be any number of rows and columns. Each pixel element **70.9** comprises a photosensor structure and an active pixel circuit indicated generally by reference numeral **72.9** and **170** respectively. The pixel element **70.9** is further illustrated in FIG. **10**, wherein the active pixel circuit **170** is presented in greater detail. The operation of the pixel elements **70.9** is described in great detail in Merril.

Again, referring back to FIGS. **4***b-d* and **4***f-h,* the light emitting and image sensing devices **60***b-d* and **60***f-h* include a plurality of photoemitters **68***b-d* and **68***f-h* respectively. In another embodiment, a plurality of photoemitters **68.11** in a light emitting and image sensing device is controlled by a photoemitter controller **138.11** as illustrated in FIGS. **11***a-b,* wherein like parts have like reference numerals with an additional suffix. The photoemitter controller **138.11** enables the photoemitters **68.11** to emit light, disables the emission of light and controls the intensity of emitted light. The photoemitter controller **138.11** can be an adjustable current source, for example, which is well known in the art. The light emitting and image sensing device includes the photoemitter controller **138.11**. In other embodiments, the photoemitter control means **138.11** can be external of a light emitting and image sensing device. In this case, the photoemitters **68.11** are connected to the photoemitter controller **138.11** by an electrical connector for example a connecting pin, or pad.

Referring back to FIGS. **5**, and similarly with FIGS. **6**, **7** and **8**, the trench **88** operates to reduce light transmission from the photoemitter **68.5** towards the pixel element **70.5**. In another embodiment of the invention illustrated in FIG. **12**, wherein like parts have like reference numerals with an additional suffix, a trench **88.12** separates two regions in a semiconductor layer **74.12**, for instance a silicon layer. The trench **88.12** extends from a surface **172** to a boundary surface **174** between the semiconductor layer **74.12** and a layer **78.12**, for instance a silicon oxide (SiO_2) layer. A light emitting region **62.12** and an image sensing region **64.12** correspond to the corresponding regions in the light emitting and image sensing devices **60**, **60.***b* and **60.***c* of FIGS. **4***a-c* respectively. The trench **88.12** serves to substantially reduce light transmission from the light emitting region **62.12** through the semiconductor layer **74.12** towards the image sensing region **64.12**. When the semiconductor layer **74.12** is silicon (or doped silicon) the trench **88.12** can have a wall, next to the light emitting region **62.12**, which has a film of silicon oxide (SiO_2) thereon.

In another embodiment of the invention illustrated in FIG. **13**, wherein like parts have like reference numerals with an additional suffix, a trench **88.13** in a semiconductor substrate **74.13** separates a light emitting region **62.13** and an image sensing region **64.13**. The light emitting region **62.13** and the image sensing region **64.13** correspond to the corresponding regions in the light emitting and image sensing devices **60***e-g* of FIGS. **4***e-g* respectively. Again, the trench **88.13** serves to substantially reduce light transmission from the light emitting region **62.13** through the semiconductor layer **74.13** towards the image sensing region **64.13**.

FIG. **14** illustrates another embodiment of the invention, wherein like parts have like reference numerals with an additional suffix. A plurality of trenches **88.14** in a semiconductor substrate **74.14** separate a plurality of light emitting regions **62.14** from an image sensing region **64.14**. The plurality of light emitting regions **62.14** contain photoemitters corresponding to the photoemitters **68.***h* of the light emitting and image sensing device **60.***h* of FIG. **4***h*. The image sensing region **64.14** contains a plurality of pixel elements corresponding to the pixel elements **70.***h* of the light emitting and image sensing device **60***h* of FIG. **4***h*.

Another embodiment of the invention is illustrated in FIGS. **15** and **16**, wherein like parts have like reference numerals with an additional suffix. Referring to FIG. **16** first, a light emitting and image sensing device **60.16** is mounted on a substrate **182**, for instance a printed circuit board (PCB), and a single light channel housing **180** is mounted to the substrate overtop the light emitting and image sensing device. The light emitting and image sensing device **60.16** in this embodiment can be the device **60.***h* illustrated in FIG. **4***h*.

Referring to FIGS. **15** and **16**, the single channel housing **180** has a first end **184** and a second end **186** and a light channel **185**. A lens **188** is attached at the first end **184**. The first and second ends **184** and **186** can have different shapes, for instance circular, square or rectangular. The light channel **185** has an inner surface **187**. The inner surface **187** can be shaped such that at the first end **184** it is one shape, for instance annular, and at the second end **186** it is a second shape, for instance square, with a smooth transformation of the inner surface between the ends **184** and **186**.

Another embodiment of the invention is illustrated in FIGS. **17** and **18**, wherein like parts have like reference numerals with an additional suffix. Referring to FIG. **18** first, a light emitting and image sensing device **60.18** is mounted on a substrate **182.18**, and an adjacent light channel housing **180.18** is mounted to the substrate overtop the light emitting and image sensing device. The light emitting and image sensing device **60.18** in this embodiment can be either one of the devices **60.***e,* **60.***f* and **60.***g* illustrated in FIGS. **4***e,* **4***f* and **4***g* respectively.

Referring to FIGS. **17** and **18**, the adjacent light channel housing **180.18** has a first light channel **190** adjacent a second light channel **192**. The first light channel **190** has opposite ends **194** and has a lens **198** attached at one end thereof. The lens **198** can be biconcave as well as other types of diverging lenses. Light from a light emitting region **62.18** of the light emitting and image sensing device **60.18** travels through lens **198** towards a scene, or an object. The lens **200** can be biconvex as well as other types of converging lenses. The opposite ends **194** can have different shapes, for instance circular, rectangular or square. The second light channel has opposite ends **196** and has a lens **200** attached at one end thereof. Light from the scene or the object travels through lens **200** towards an image sensing region **64.18** of the light emitting and image sensing device **60.18**. The opposite ends **196** can have different shapes, for instance circular, rectangular or square.

Another embodiment of the invention is illustrated in FIGS. **19** and **20**, wherein like parts have like reference numerals with an additional suffix. Referring to FIG. **20** first, a light emitting and image sensing device **60.20** is mounted on a substrate **182.20**, and a dual light channel housing **180.20** is mounted to the substrate overtop the light emitting and image sensing device. The light emitting and image sensing device **60.20** in this embodiment can be either of the devices **60**, **60**.*b* and **60**.*c* of FIGS. **4***a,* **4***b* and **4***c* respectively.

Referring to FIGS. **19** and **20**, the dual light channel housing **180.20** has a first light channel **190.20**, having an axis **191**, and a second light channel **192.20** having the same axis **191**. The first light channel has opposite ends **194.20** and has a lens **198.20** attached at one end thereof. The lens **198.20** can be biconcave as well as other types of diverging lenses. Light from a light emitting region **62.20** of the light emitting and image sensing device **60.20** travels through the lens **198.20** and towards a scene, or an object. The opposite ends **194.20** can have different shapes, for instance circular, rectangular or square. The second light channel has opposite ends **196.20** and has a lens **200.20** attached at one end thereof. The lens **200.20** can be biconvex as well as other types of converging lenses. Light from the scene, or the object, travels through the lens **200.20** towards an image sensing region **64.20** of the light emitting and image sensing device **60.20**. The opposite ends **196.20** can have different shapes, for instance circular, rectangular or square. Typically, the shapes of the opposite ends **194.20** of the first light channel **190.20** correspond to the shapes of the opposite ends **196.20** of the second light channel **192.20**.

Another embodiment of the invention is illustrated in FIG. **21** wherein like parts to previous embodiments have like reference numerals with an additional suffix '**21**'. A first semiconductor substrate **120.21** is illustrated above a second semiconductor substrate **122.21**. The first semiconductor substrate **120.21** can be formed from III-V or II-VI compound semiconductor materials, or organic polymers, whereas the second semiconductor substrate **122.21** is formed from silicon. A photoemitter **68.21** is formed in the first semiconductor substrate **120.21**, and a pixel element **70.21** is formed in the second semiconductor substrate **122.21**. The pixel element **70.21** is similar to the pixel element **70.5** in FIG. **5**. The photoemitter **68.21** can be in the form of an infrared LED, an organic LED, or an RGB LED.

Another embodiment of the present invention is illustrated in FIGS. **22**, **23** and **24** wherein like parts to previous embodiments have like reference numerals with an additional suffix '**22**'. There is a light emitting and image sensing device **60.22** connected with a printed circuit board **212**. The light emitting and image sensing device **60.22** has a plurality of pixel elements **70.22** on one side of the device **60.22**. The pixel elements **70.22** transform image light into electrical signals. On the opposite side of the device **60.22** is a photoemitter **210**. The photoemitter **210** is electrically coupled to the pixel elements **70.22**, however other forms of coupling such as optical coupling can be used. The photoemitter **210** sequentially emits light signals representative of respective ones of the electrical signals of the pixel elements **70.22**. In other embodiments, the electrical signals of the pixel elements **70.22** can be encoded into an encoded signal, which can be emitted in the form of an encoded light signal by the photoemitter **210**. The photoemitter **210** transfers the electrical image captured by the device **60.22** off the device into an optical coupler **216** through a channel **214** in the printed circuit board **212**. The optical coupler **216** is connected with a fiber optic cable **218** which carries the light signals generated by the photoemitter **210** to a remote desination.

Referring to FIG. **24**, a more detailed description of the light emitting and image sensing device is now given. A first semiconductor substrate **122.22** is illustrated above a second semiconductor substrate **120.22**. The first semiconductor substrate **122.22** is formed from silicon. The second semiconductor substrate **120.22** can be formed from III-V or II-VI compound semiconductor materials, or organic polymers. A pixel element **70.22** is formed in the first semiconductor substrate **122.22**. The pixel element **70.22** is similar to the pixel element **70.5** in FIG. **5**, however other pixel element structures are possible. A photoemitter **210** is formed in the second semiconductor substrate **120.22**. The photoemitter **210** can be in the form of an infrared LED, an RCLED, or a VCSEL, as described previously, but other forms are possible as well. The pixel elements **70.22** can be arranged in a matrix configuration as illustrated in FIG. **9** and described previously. Each of the pixel elements **70.22** is similar to the pixel element illustrated in FIG. **10** and described previously. Note that other pixel element configurations and structures are possible, and this example is not intended to limit the invention. The photoemitter **210** can include a photoemitter controller, similar to that illustrated in FIGS. **11***a* or **11***b,* and described earlier, however other photoemitter controllers are possible. Note that in other embodiments the photoemitter **210** can be formed in a silicon layer **78.22** of the first semiconductor substrate **122.22**, e.g. similar to the photoemitter in FIGS. **5** and **6**.

As will be apparent to those skilled in the art, modifications can be made to the above-described invention within the scope of the appended claims.

What is claimed is:

1. A light emitting and image sensing apparatus comprising:

a light emitting and image sensing device including:

a photosensor means for sensing an image of the scene, the photosensor means being on a first semiconductor substrate and being responsive to incident light from the scene;

a photoemitter means for illuminating the scene with light, the photoemitter means being on a second semiconductor substrate, the second semiconductor substrate being connected with the first semiconductor substrate; and

a photoemitter control means for controlling an emission of light from the photoemitter means, the photoemitter control means being on the first semiconductor substrate;

a third substrate connected with the light emitting and image sensing device;

a means for focusing the light from the scene onto the photosensor means;

wherein the means for focusing is connected with the light emitting and image sensing device.

2. The apparatus as claimed in claim **1**, further comprising a means for directing the light from the photoemitter means to the scene, the means for directing being connected with the light emitting and image sensing device.

3. The apparatus as claimed in claim **2**, wherein the means for focusing light from the scene is connected with the means for directing light to the scene.

4. The apparatus as claimed in claim **1**, where the means for focusing includes a lens.

5. The apparatus as claimed in claim **2**, wherein the means for directing includes a lens.

6. The apparatus as claimed in claim **2**, wherein the means for directing light is located near one end of the light emitting and image sensing device, and the means for focusing is located near an end opposite the one end of the light emitting and image sensing device.

7. The apparatus as claimed in claim **2**, wherein the means for directing light is located near and around the periphery of the light emitting and image sensing device, and the means for focusing is located near the center of the light emitting and image sensing device.

8. The apparatus as claimed in claim **1**, wherein the means for focusing the light from the scene onto the photosensor means further functions to direct light from the photoemitter means to the scene.

9. The apparatus as claimed in claim **6**, further including a first light channel from the photoemitter means of the light emitting and image sensing device to the means for directing, and a second light channel from the means for focusing to the photosensor means of the light emitting and image sensing device.

10. The apparatus as claimed in claim **7**, further including a first light channel from the photoemitter means of the light emitting and image sensing device to the means for directing, and a second light channel from the means for focusing to the photosensor means of the light emitting and image sensing device.

11. A light emitting and image sensing apparatus comprising:

a light emitting and image sensing device including:

a photosensor means for sensing an image of the scene being on a first semiconductor substrate and being responsive to incident light from the scene, the photosensor means including:

a plurality of select lines;

a plurality of signal lines; and

a plurality of pixel elements, each pixel element including:

a photosensor structure; and

switching means for conveying a photosensor signal between the photosensor structure and one of the plurality of signal lines, the switching means being coupled between the photosensor structure and the one of the plurality of signal lines, the switching means being responsive to select signals on one or more of the plurality of select lines for conveying the photosensor signal;

a photoemitter means for illuminating the scene with light, the photoemitter means being on a second semiconductor substrate, said photoemitter means including a resonator, the second semiconductor substrate being connected with the first semiconductor substrate;

a third substrate connected with the light emitting and image sensing device; and

a means for focusing the incident light from the scene onto the photosensor means;

wherein the means for focusing is connected with the light emitting and image sensing device.

12. The apparatus as claimed in claim **11**, further comprising a means for directing the light from the photoemitter means to the scene, the means for directing being connected with the light emitting and image sensing device.

13. The apparatus as claimed in claim **12**, wherein the means for focusing light from the scene is connected with the means for directing light to the scene.

14. The apparatus as claimed in claim **11**, where the means for focusing includes a lens.

15. The apparatus as claimed in claim **12**, wherein the means for directing includes a lens.

16. The apparatus as claimed in claim **12**, wherein the means for directing light is located near one end of the light emitting and image sensing device, and the means for focusing is located near an end opposite the one end of the light emitting and image sensing device.

17. The apparatus as claimed in claim **12**, wherein the means for directing light is located near and around the periphery of the light emitting and image sensing device, and the means for focusing is located near the center of the light emitting and image sensing device.

18. The apparatus as claimed in claim **11**, wherein the means for focusing the light from the scene onto the photosensor means further acts to direct light from the photoemitter means to the scene.

19. The apparatus as claimed in claim **16**, further including a first light channel from the photoemitter means of the light emitting and image sensing device to the means for directing, and a second light channel from the means for focusing to the photosensor means of the light emitting and image sensing device.

20. The apparatus as claimed in claim **17**, further including a first light channel from the photoemitter means of the light emitting and image sensing device to the means for directing, and a second light channel from the means for focusing to the photosensor means of the light emitting and image sensing device.

* * * * *